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... zu kommen ...



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The Significance of the 1845 Gauss-Weber Correspondence

by Laurence Hecht

The 1830's experiments of Carl Friedrich Gauss and Wilhelm Weber to test Ampère's electrodynamic theory, led to the conception of the electron and atomic nucleus, more than 50 years before their empirical confirmation.

A letter of 19 March 1845 from Carl Friedrich Gauss to his younger collaborator, Wilhelm Weber, ranks as one of the most singular interventions of all time by an individual in changing the course of history. Modern atomic science, physics, and chemistry, and everything in the modern world that depends upon them, would not have existed without it. It is, thus, one of the clearest proofs of the existence of the consumer fraud, which passes for university science education today, that the issues discussed in the letter are scarcely known to any but a few specialists today, and that not even one among these shows any adequate understanding of the fundamentals involved.

The point at issue in the cited correspondence, is the existence of a special form of scientific concept, known to Plato as the *Idea*, which had been introduced into electrodynamics by André-Marie Ampère some 20 years earlier. No other scientist in the world at the time recognized the significance of this aspect of Ampère's work. Gauss, in the 1845 letter, points to precisely this, and successfully provokes a reorientation of Weber's thinking. As a result, Weber develops a generalization of Ampère's law that leads, by no later than 1870, to the theoretical recognition of the existence of the charged atomic nucleus and oppositely charged orbiting electrons, decades before any empirical identification of the phenomena could be made. By that year, Weber had also derived the precise formula (e^2/mc^2) for the atomic measurement later known as the *classical electron radius*, and identified the nuclear binding force, a phenomenon for which there was no empirical evidence until the 20th century.

The fact that these discoveries of Weber are virtually unknown today, is itself a scandal, although not the main point

of our treatment here. We focus rather on the more crucial underlying point: the method of Ampère, Gauss, and Weber; that is, the actual scientific method, which alone leads to fundamental discovery. The 1845 correspondence offers a precious inside view into the process.

First, the essential background:

In 1820, Hans Christian Oersted first demonstrated the effect of an electrical current on a magnet (Figure 1). Biot, Savart,

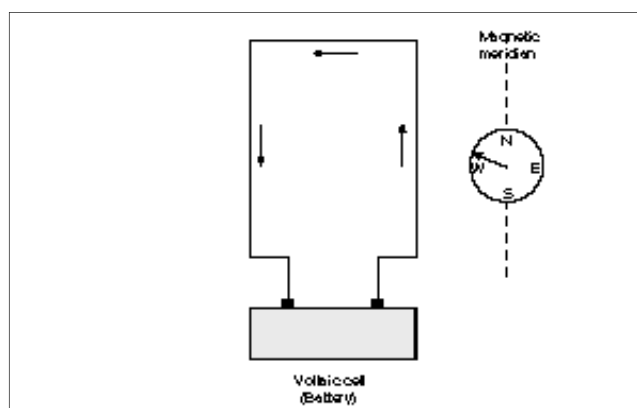
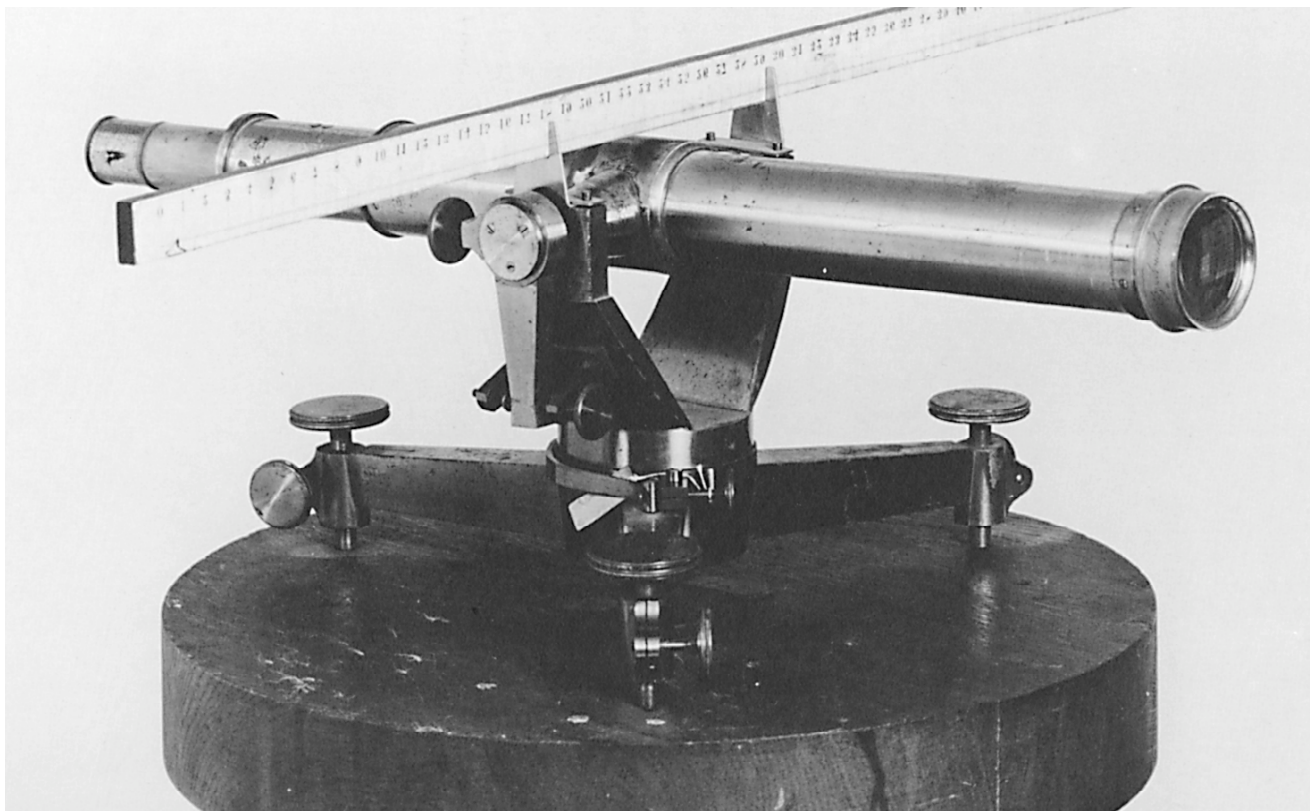


Figure 1
THE OERSTED EXPERIMENT

Hans Christian Oersted first definitively demonstrated a relationship between electricity and magnetism. He showed that a magnetic compass needle, placed near a current-carrying wire, will turn in the direction of the wire.



This telescope and meter stick were built by the firm Utzschneider und Fraunhofer of Munich, probably in 1880. It is, in principle, the same as that devised by Gauss in 1832 for the precise observation of angular deflection in connection with his determination of the absolute intensity of the Earth's magnetic force. A plane mirror, attached to a rotatable magnet, projects the image of whatever part of the meter stick it faces, into the telescope tube. The scale numbers are thus mirror-reversed and inverted for reading through the telescope sight. Weber's 1841 version of the apparatus could produce an angular precision of about 18 seconds of arc. (See Figure 1.3, page 37 for details of the Spiegel und Fernrohr apparatus.)

and others among the leading establishment physicists in France, encouraged by Laplace, undertook empirical investigations to determine the measurable effect of the conducting wire on a magnet. Ampère, recognizing that current (Galvanic) electricity represented a completely new phenomenon, saw in Oersted's demonstration the possibility of gaining fundamental new knowledge of magnetism and the atomic constituency of matter. Hypothesizing that magnetism itself may be the result of electrical currents surrounding the molecules of matter, he set out first to determine if two electrical conductors affected each other in the same way that a single electric wire affects a magnet. His first experiments established that two parallel conducting wires attract or repel, depending on whether their currents flow in similar or opposing directions. He next demonstrated that, by passing a current through a helically coiled wire, the configuration, which Ampère first named a solenoid, developed north and south magnetic poles, just like a bar magnet (Figure 2).

Having thus discovered, within a few weeks' time, the first empirical laws of a new science—he named it *electrodynamics*—Ampère next set himself the task of determining its fundamental laws. He thus proposed to find a formula expressing the interaction between two hypothetical, very small portions of electrical current, which he called *current elements*, in adjacent conducting wires. His results were sensational. At the time, the laws of gravitation, static electricity, and magnetism had all been found to be dependent on the inverse square of

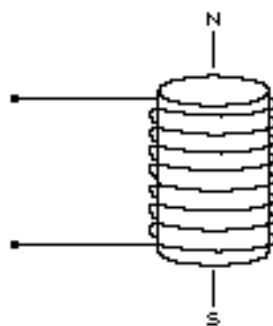


Figure 2
THE AMPERE SOLENOID

Ampère hypothesized that the true cause of magnetism is the motion of resistance-less electrical currents in tiny orbits around the molecules of matter. To prove it, he constructed the world's first electromagnet, a conducting wire coiled around a cylinder, which he named a solenoid. When the solenoid is attached to a battery, the ends of the cylinder become like the north and south poles of a bar magnet. Ampère believed that the large-scale circular motion of the electricity in the solenoid coil mimicked the tiny circular orbits which he conceived to be present in a magnet.

the distance of separation of their elements (mass, charge, and magnetic *molecules*). But Ampère's law of force for current elements showed a dependence not only on the distance, but on the directions of the current elements.

The Method of Hypothesis

The existence of such an anomaly, defying the neat unification of forces only recently established, was disturbing to many. For more than 20 years, Ampère's work, although well known to scientists, was never treated seriously. Although many criticized it, no one before Weber ever troubled to test it. The essential problem militating against its acceptance, was the philosophic outlook known as *empiricism*. A prevailing view in science then, as now, empiricism demanded that no physical phenomena could be measured, and thus subjected to the rigorous mathematical analysis expected of the pure sciences, unless one could see, hear, feel, smell, or taste it.

The method of hypothesis employed by Ampère, assumes, rather, that the so-called *data* of the senses are completely delusional. Nothing that one can see, hear, feel, smell, or taste is what it appears to be. Take a simple object like a magnetized steel bar, for example. An empiricist might measure and analyze the effect on it of an electrical wire all day long; he might cut it in half, grind it up into a powder, dissolve it in acid, or melt it in an oven, and never yet arrive at the simple *hypothesis* that its magnetic property derives from the existence of very small, electrical currents circling the invisible particles which constitute it.

But to merely formulate such an idea, is only the first small step in the pursuit of the method of hypothesis. It is necessary, above all, to seriously *believe* in the existence of such non-observable things. One must have a truly passionate belief, not unlike the proper meaning of the word *faith*, in the *reality* of such a mere idea. Only by such a driving passion, a *love of the idea*, can a person be motivated to pursue it, as Ampère did,

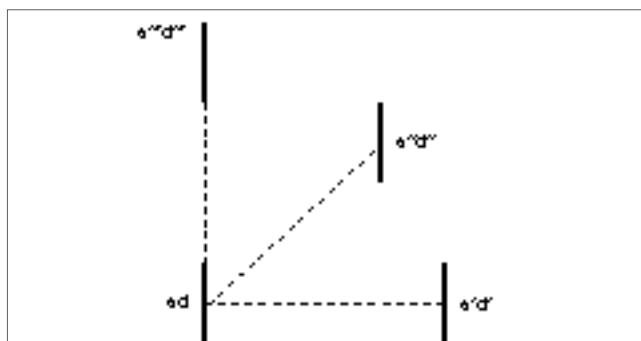


Figure 3

THE FORCE BETWEEN CURRENT ELEMENTS

Early experiments with two parallel wires showed that the wires attracted each other when the current flowed through them in the same direction, and repelled in the opposite case. From this Ampère could conclude that any two parallel, small sections of the wire (current elements) would behave accordingly. This is the relationship of element ad to $a'd'$ in the diagram. But what if the second element is in another position, such as that of $a''d''$ or $a'''d'''$? Direct observation could not decide these more general cases.

through five years of experimental design and mathematical analysis, before he felt sure of its truth. And if the *idea* is of a fundamental sort, as was Ampère's concept of electrical action, it will tend to overthrow previously existing conceptions. In this case, the existence of a force dependent on angular relationship, clearly challenged the Newtonian conception. The laws of physics would not allow it—and yet it existed.¹

Gauss appreciated Ampère's accomplishment as few, if any, others did. His letter of 19 March 1845 focusses on an aspect of Ampère's hypothesis, that is an Idea, known as the *longitudinal force*. This is a simple construct, relying only on elementary relationships of geometry, but so controversial that many have denied its existence for almost two centuries. As an understanding of it is crucial for the rest of the story, let us summarize how Ampère develops it.

1. The Essentials of Ampère's Law

Consider first, two current elements, ad and $a'd'$, parallel to each other and perpendicular to the line connecting their midpoints (Figure 3). Ampère knew from his first experiment with parallel wires, that the current elements will attract or repel depending on whether the current in the wires of which they are a part flows in the same or opposite directions. But what about the current elements in other positions, such as $a''d''$ or $a'''d'''$? How does the force between them differ when the second current element is positioned *longitudinally*, that is, on a straight line with the first, as at $a'''d'''$? Let the ratio of the force between the current elements in the longitudinal position to those which are parallel be designated by the constant k . What is its value? Two current elements cannot be isolated from the circuits of which they are a part, to be placed in these positions. Thus it is not possible to carry out a direct empirical measurement of the force between them. The method of hypothesis is the only one available to answer the question. Here is how Ampère proceeds in what is known as his Second Equilibrium Experiment:

Two parallel, vertical columns are placed a small distance apart on a laboratory table. Between them, a rectangular wire circuit is placed so that one side of the rectangle is parallel to the two columns and forms a common plane with them. The rectangle is free to swing on a vertical axis (Figure 4). In the first case, straight conducting wires are led up each of the vertical columns, and a current is made to flow through both of them in the same direction, either up or down. A current of the opposite direction is caused to flow through the parallel side of the rectangle GH . When the current is turned on, he finds that the rectangle remains positioned in the center between the two parallel wires in the vertical columns.

In the second case, the wire, kl , running up one of the columns, RS , is made to snake arbitrarily back and forth in the plane perpendicular to the paper—Figure 4 (b). But when the current is turned on, it makes no difference. The side, GH , of the movable rectangle still positions itself in the center between the two columns, and does so even when the pattern of bends in the wire kl is changed.

To explain this paradox, Ampère analyzes the current flow in the bent wire into its components in the vertical and horizontal direction. Both the bent and straight wires stretch along the same vertical length, hence the sum of the vertical components of kl is the same as bc . As the first case shows that no

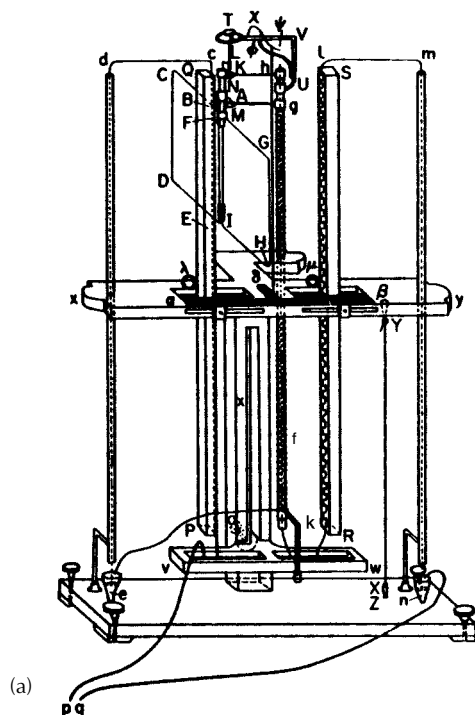
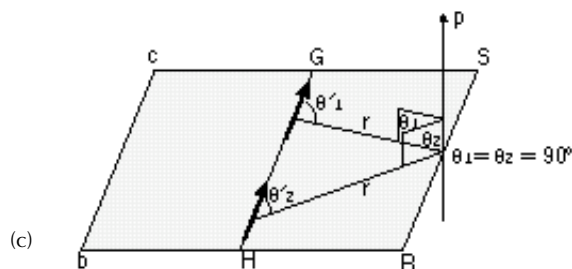
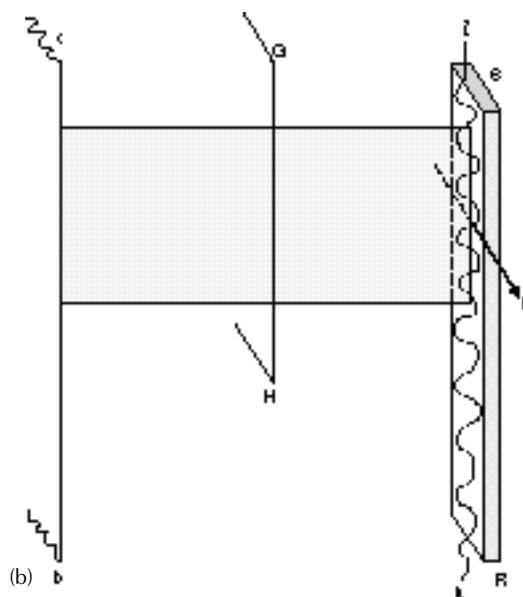


Figure 4

AMPERE'S SECOND EQUILIBRIUM EXPERIMENT

Ampère's most important law of interaction of current elements can be deduced from his Second Equilibrium Experiment. The copperplate (a) of the apparatus is from Ampère's 1826 Memoir. The two wooden posts PQ, RS are slotted on the sides which mutually face each other. A straight wire runs up PQ, while the wire in the slot of RS snakes back and forth in the plane perpendicular to PQRS. The wire rectangle CDGH also conducts a current and is free to rotate about the axis ML.

The purpose of the experiment is to determine whether the snaking of the wire in RS causes a rotation of the wire rectangle CDGH. The circuit is arranged so that current flows up the two fixed conductors in PQ and RS and down the side of the movable rectangle denoted GH. The entire apparatus is a single circuit. Current enters at the mercury-filled trough v, and leaves through the mercury cup at n. The wire passing up the vertical glass tube fgh is wound helically to negate its magnetic effect in a lateral direction.



The vertical columns de and mn are glass tubes for the return circuit.

In (b) we see a schematic detail of the relationship of the two fixed conductors and the side GH of the movable rectangle: p is the horizontal component of current flow at an arbitrary point of the snaky wire kl. The shaded rectangle depicts the plane RScb to which p is perpendicular.

In (c), the rectangle RScb has been rotated 90 degrees so that the current element p now appears vertical. The midpoints of the two arbitrary current elements depicted in the plane RScb are connected by the lines r to the midpoint of p. The angle formed by r at p (θ_1, θ_2) is always right. The experiment shows that regardless of the other angle (θ_1, θ_2), the current element p exerts no force on any current element in the plane RScb.

motion arises from two parallel vertical wires, the vertical components of kl may thus be ignored. Thus the problem reduces to an examination of its horizontal components.

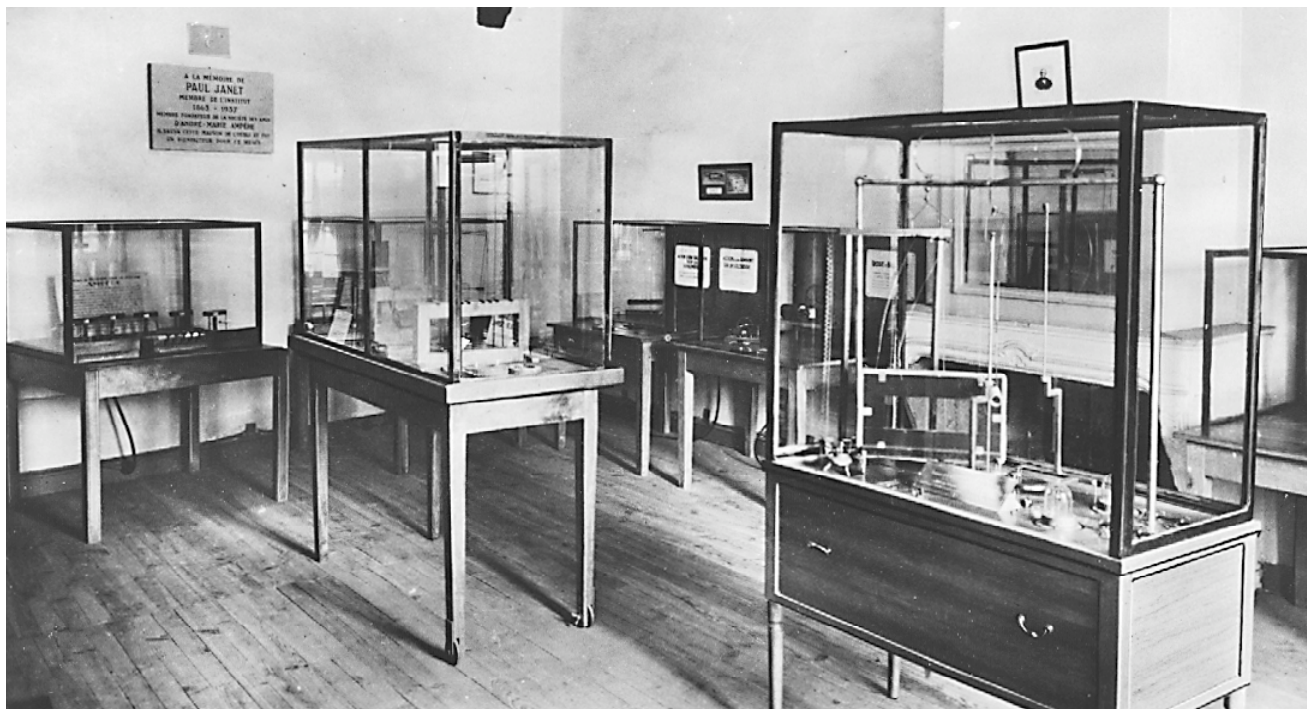
Take any horizontal component, for example the one at the arbitrary position p in Figure 4(b), which is, by definition, perpendicular to the shaded plane RScb. Consider its relationship to any current element in the movable wire GH. By virtue of the fact that GH does not move, we can conclude that the arbitrarily chosen horizontal component must have no interaction with any current element along the length of GH. If it had any interaction, a disequilibrium of forces would necessarily arise from the arbitrary bends in the wire, causing GH to move.

From this experimentally deduced fact, Ampère is able to

adduce the following theorem for the interaction of current elements:

. . . that an infinitely small portion of electrical current exerts no action on another infinitely small portion of current situated in a plane which passes through its midpoint, and which is perpendicular to its direction. [Ampère 1826, p. 202]

Figure 4(c) helps us to see how the generalization is made. The plane RScb has been rotated 90 degrees. The horizontal component is here pictured as the arrow, p, passing vertically through the plane. The other two arrows represent arbitrary



Ampère's electrical apparatus is on display at a small museum in his childhood home at Poleymieux, France.

current elements in GH . These may make any angles whatsoever with the lines r connecting them to the midpoint of p . Since the experiment shows that the current element p exerts no action on any of them, the generalization is made that p exerts no action on any current element anywhere in the plane.

One might first imagine that we could establish the same result by simply placing two wires perpendicular to each other, a certain distance apart, and directly measuring the effect. The problem is that it is only the infinitesimal elements of the two wires, precisely at the point of perpendicularity which concern us, while in the mooted simplified configuration, all the other elements of the two wires will also contribute to the measured effect. One sees then, the genius of the Second Equilibrium Experiment, that it allows us to isolate—although only by abstraction—precisely the effect we wish to measure. This is true, indeed, of all four equilibrium experiments; the reader should know that Ampère carried out many dozens, perhaps hundreds, of other experiments before being able to reduce his presentation to deduction from the four equilibrium experiments presented in his final 1826 *Memoire* on electrodynamics.

The theorem deduced from the second experiment is the key that allows Ampère to solve the problem posed in connection with Figure 3. Return to Figure 3, where ad and $a'd'$ are two parallel current elements. The question he poses is how the force between them changes as the current element is repositioned from $a'd'$ to $a''d''$. Ampère determines that he will define the force as a function of the current element lengths, the intensities of the current of which they are part, and their relative position; the force is to be represented as acting along the line r .

Since the current elements under consideration lie in a plane, their relative position will be completely described by

the length of the line, r , connecting their midpoints, and the angles θ, θ' which they form with it—Figure 5(a). "Consideration of the diverse attractions and repulsions observed in nature," writes Ampère,

led me to believe that the force which I was seeking to represent, acted in some inverse ratio to distance; for greater generality, I assumed that it was in inverse ratio to the n th power of this distance, n being a constant to be determined. [Ampère 1826, p. 200]

If the very small lengths of the current elements are represented as ds, ds' , their intensities as i, i' , and θ, θ' designate the angles they form with the line connecting them, then the force between them, based on the assumptions so far, will be

$$\frac{ii' ds \cdot ds'}{r^n} \phi(\theta, \theta'),$$

where ϕ represents the unknown function of the angles between the two current elements.

This leaves two unknowns to be determined: the value of the exponent, n , and the angle function, ϕ . The results of the second equilibrium experiment make it an easy matter to find the angle function ϕ . Take two arbitrary current elements in a plane, ds and ds' , and resolve their directions into two perpendicular components, as pictured in Figure 5(b). The parallel components will be represented by $ds \sin\theta$ and $ds' \sin\theta$. The longitudinal components will be represented by $ds \cos\theta$ and $ds' \cos\theta$. By the theorem derived from the second equilibrium experiment, we see that the force between $ds \sin\theta$ and $ds' \sin\theta$, and also that between $ds' \sin\theta$ and $ds \cos\theta$ is zero. This may appear confusing at first, because the two perpendicular

elements under consideration in Figure 4 are not, in general, in the same plane. But the theorem deduced from the Second Equilibrium Experiment subsumes the planar case, as the reader can see from Figure 5(c).

The action of the two elements ds and ds' therefore reduces to the two joint remaining actions, namely the interaction between $ds \sin\theta$ and $ds' \sin\theta'$, and between $ds \cos\theta$ and $ds' \cos\theta'$. It is easy to see that these two pairs of actions are between components which are either *parallel* or *longitudinal*. The first can be represented as

$$\frac{ii' ds \cdot ds' \sin\theta \sin\theta'}{r^n},$$

and the second as

$$\frac{ii' ds \cdot ds' k \cos\theta \cos\theta'}{r^n},$$

remembering that k represents the ratio of the longitudinal to the parallel force, taking the parallel force as unity. It is only necessary to add these to obtain the total force between the two current elements, which produces:

$$\frac{ii' ds \cdot ds'}{r^n} (\sin\theta \sin\theta' + k \cos\theta \cos\theta'). \quad \text{Eq. 1}$$

With only one simplification, introduced to ease the reader's burden, this is the general expression for the Ampère force under discussion in the 1845 correspondence between Gauss and Weber. For simplicity's sake, we derived the formula for the plane only. If the two current elements are not restricted to a plane, but may lie in planes whose angle with each other is represented by ω , then the full expression for the Ampère force becomes:

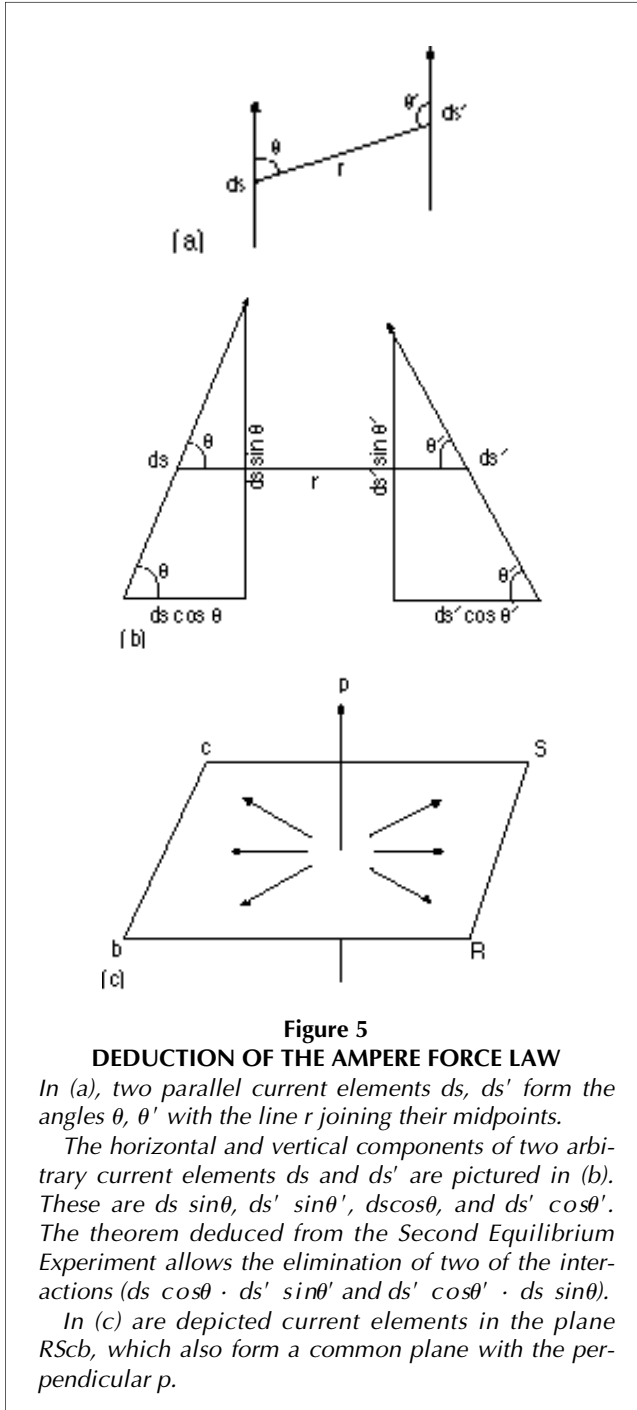
$$\frac{ii' ds \cdot ds'}{r^n} (\sin\theta \sin\theta' \cos\omega + k \cos\theta \cos\theta').$$

The determination of the values of the constants n and k , required two additional equilibrium experiments, which allowed Ampère to derive the values $n = 2$ and $k = -1/2$.

2. The Ampère Formula and the Correspondence

In 1828, Wilhelm Weber, a young physics graduate who had distinguished himself through original research into acoustics and water waves, met Carl Friedrich Gauss, then the leading astronomer and mathematician of Europe, at a scientific conference in Berlin. Gauss needed help to carry out the researches he planned in magnetism and electricity, and Alexander von Humboldt encouraged their cooperation. Weber was awarded a professorship at Göttingen University and began work there in 1831. Their joint researches on magnetism led to the first determination of an absolute measurement of the Earth's magnetic force and a seminal paper by Gauss on the subject in 1832. In 1833, the two constructed the world's first electromagnetic telegraph, running from the university observatory to the physics laboratory. Gauss had identified the confirmation of Ampère's law as one of the leading tasks facing science, and Weber began a long series of experiments to that end. The Gauss magnetometer was adapted into an instrument, the *electrodynamometer*, for bringing to electrical measurements the precision which Gauss had achieved for magnetism. (See accompanying article, p. 35.)

In 1845, Weber, now at Leipzig, was preparing a treatise on his results, which he wished to present to the Royal Society in Göttingen. Uncertain of his conclusions, he sent a copy to Gauss on 18 January 1845, asking for his evaluation. On 1 February 1845, Weber sent a second letter explaining a change he had made in the Ampère formula,





Deutsches Museum

This experimental apparatus for replicating the electrodynamic experiments of Ampère was designed by H. Pixii in 1824, and is on display at the Deutsches Museum in Munich.

which I seek to justify, by means of the consideration that the empirically derived definition of the coefficient of the second term, which I have discarded, seems completely untrustworthy, because of the unreliability of the method, and hence that coefficient, so long as it lacks a more precise quantitative determination, by the same reasoning would have to be set = 0.

The coefficient Weber refers to is that identified just above as k . The second term, $k \cos\theta \cos\theta'$, is the longitudinal force, which Weber proposes to drop. It is perhaps not irrelevant that in the year 1845, an article by Hermann Grassmann in the physics journal, Poggendorf's *Annalen*, challenged the angle dependency of the Ampère force, describing the existence of such an effect as "improbable." Weber was a friend of the journal's editor, Poggendorf, and had recently worked with him in Berlin. Weber would thus have likely known in advance of Grassmann's contribution on the topic that had occupied him for more than a decade. Perhaps Grassmann's effort, combined with his separation from Gauss, propelled Weber into self-doubt about the reality of the Ampère hypothesis.

Gauss's rejoinder of 19 March is the singular intervention referred to in opening this article. In his 70th year, Gauss begins with regrets over the loss of time caused by his poor health, and his decade of removal from work on the topic. But, of the proposed modification of the law, Gauss writes, with no loss of acuity:

. . . I would think, to begin with, that, were Ampère still living, he would decidedly protest . . . [I]n the present case, the difference is a vital question, for Ampère's entire theory of the interchangeability of magnetism with galvanic currents depends absolutely on the correctness of [his formula] and is wholly lost, if another is chosen in its place.

. . . I do not believe that Ampère, even if he himself were to admit the incompleteness of his experiments, would authorize the adoption of an entirely different formula, whereby his entire theory would fall to pieces, so long as this other formula were not reinforced by completely decisive experiments. You must have misunderstood the reservations which, according to your second letter, I myself have expressed. . . .

To see clearly what Gauss is saying, the reader must know that prior to Ampère, magnetism had been explained as a separation (polarization) of two *magnetic fluids*, boreal and austral, within the particles (*magnetic molecules*) of a magnetizable substance. Magnetizing an iron bar was seen to consist of polarizing and aligning the magnetic molecules along a given axis of the bar. Ampère suggested rather that the magnetic molecule is an electrical current loop, a "*galvano-electric orbit*," as Gauss was to characterize the Ampère magnetic hypothesis in his 1832 study of magnetism. Magnetization, for Ampère, consisted of aligning these microscopic current loops along the magnetic axis. In his 1826 treatise, Ampère had elaborately developed the interdependence of his new magnetic hypothesis with his formula for the force between two current elements.

Weber completely accepted Gauss's correction and wrote back on 31 March:

It has been of great interest to me to learn from what you were kind enough to write, that Ampère, in the definition of the coefficient he calls k in his fundamental law, was guided by other reasons than the ones from immediate empirical experience which he cites at the beginning of his treatise, and that hence the derivation, which I first gave, because it seemed somewhat simpler, is inadmissible, because it does not reproduce Ampère's law with exactness; yet, by means of what seems to me to be a slight modification in my premise, I have easily obtained the exact expression of Ampère's law.

3. The Development of Weber's Law

Over the previous 10 years, Weber had been engaged in the experimental confirmation of Ampère's law. The measuring instrument he had developed, the *electrodynamometer*, consisted of a fixed and a rotatable helically wound electromagnet. (See accompanying article, p. 35.) The rotatable one, suspended by two wires whose torsion could be accurately measured, came to be known as the *bifilar coil*. A precisely measured current was passed through the two coils, and the angle of rotation observed by means of a precision system developed by Gauss for his magnetometer, consisting of a mirror and telescope. The effect of the Earth's magnetic force could be precisely determined, and thus eliminated, using the system already developed by Gauss. Hence the experimental



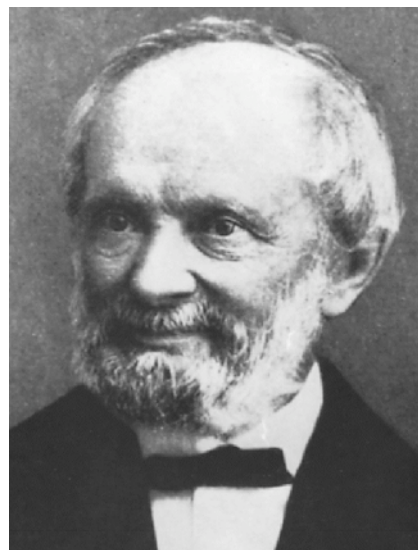
Courtesy of the Museum of Electricity at Poleymieux

André-Marie Ampère (1775-1836)



Lithograph by Siegfried Bendixen, courtesy of Historical Collection of the Göttingen University I. Physical Institute

Carl Friedrich Gauss (1777-1855)



E. Scott Barr Collection, American Institute of Physics
Emilio Segrè Visual Archives

Wilhelm Eduard Weber (1804-1891)

data could be reduced to yield the exact rotational moment exerted between the two Ampère solenoids.

Ampère had already shown in his famous treatise (Ampère 1826), how to calculate the rotational moment exerted by a single circular current loop on a current element in any position in space. The force was dependent on the current strength, the distance of separation, and the area enclosed by the loop, all values which were determined in the Weber apparatus. By treating the helically wound coils as a compound of such current loops and integrating their effect, Weber was able to calculate with precision the angular rotation that should be imparted to the bifilar coil. His measurements, achieved under a variety of experimental conditions, conformed to the calculated values within one-third of a scale unit, or less than 6 seconds of arc.

Despite this complete agreement between theory and measurement, which Weber had already determined before 1845, there had remained the possibility that the Ampère law was not correct in all its specificity, and that a simpler generalization, discarding the longitudinal force, might suffice. After receipt of Gauss's 19 March letter, with full confidence in the master's judgment, Weber forged ahead into new territory.

The task he set himself was to find a generalization of Ampère's law that would encompass the phenomena of voltaic induction, discovered by the American, Joseph Henry, five years after Ampère had completed his work in electrodynamics. This included the following effects:

- the appearance of an electrical current in a closed circuit when there is relative motion between it and a current-carrying wire in its vicinity.
- the appearance of an electrical current in a closed circuit when there is a change in the intensity of current in a neighboring conductor.

Ampère's electrodynamic law applied only to moving currents in fixed conductors. Beside it, stood the separate law of

electrostatic force. The existence of the phenomenon of induction suggested to Weber that a true, fundamental law of electricity would have to subsume the electrostatic and electrodynamic laws under a new, more general form. A conception developed by his colleague, Gustav Fechner, proved to be of crucial value.

Fechner had extended the Ampère conception of the current element by considering the flow of electricity as consisting of oppositely charged electrical particles moving through the conductor with equal velocity in opposite directions. (Today, we assume that the positive electrical particle is virtually stationary and that the negative particle moves, a modification first suggested by Wilhelm Weber.) In any small segment of the wire, a positive and a negative particle would be found speeding past one another. Thus, the interaction between two current elements involved four interactions among electrical particles. If the current elements are labeled e and e' , there are the following four relationships:

- (1) between $+e$ and $+e'$
- (2) between $+e$ and $-e'$
- (3) between $-e$ and $-e'$
- (4) between $-e$ and $+e'$.

Since the particles, in these cases, are confined to their conductors, the forces between them are assumed to be transferred to the motion of the conducting wires themselves.

Weber now considers the situation where one current element follows the other along the same line, that is the situation described by Ampère's *longitudinal force* (Figure 6). If the electrostatic law alone applied, the two attractions of opposite particles (2 and 4) would exactly equal the two repulsions of like particles (1 and 3). But by the crucial *hypothesis* derived from Ampère's experiments, we know there will be an attraction or repulsion between the current elements, depending on the direction of current flow.

The question is, how must the electrostatic law be modified

in order to yield the longitudinal force as a result? Notice in Figure 6, Case 1, that the particles in relative motion are those of opposite charge (the like particles flow in the same direction and thus have no relative velocity). Now see, in Case 2, that it is the like particles that are in relative motion. In Case 1, the resultant force is repulsion; in Case 2, it is attraction. From this, Weber adduces the theorem *that the electrostatic force must be reduced when the electrical particles are in relative motion*, that is when they have a relative velocity.

The electrostatic law is a simple inverse square law. If e and e' are the charge of two stationary particles, and r their distance, the force between them is simply $e e' / r^2$. The *relative velocity* of two particles can be designated as dr/dt . Since the theorem of Weber applies both where the particles are approaching or receding from one another—that is, where the sign (direction) of the relative velocity is either positive or neg-

ative, Weber will use the *square*, dr^2/dt^2 . He thus expresses his theorem for the force between two electrical particles in longitudinal motion:

$$\frac{ee'}{r^2} \left(1 - a^2 \frac{dr^2}{dt^2} \right),$$

where a is a constant whose value must be determined.

The Parallel Case

The same considerations must now be applied to the case of two parallel current elements which form a right angle with the line connecting their midpoints (Figure 7). In this case, the result (attraction or repulsion depending on whether the currents flow in the same or different directions), was known to Ampère through his earliest experiments. Their interaction will now be analyzed, as in the previous case, according to Fechner's hypothesis.

The first thing we notice is that at the very instant when the current elements are directly opposite each other, the *relative*

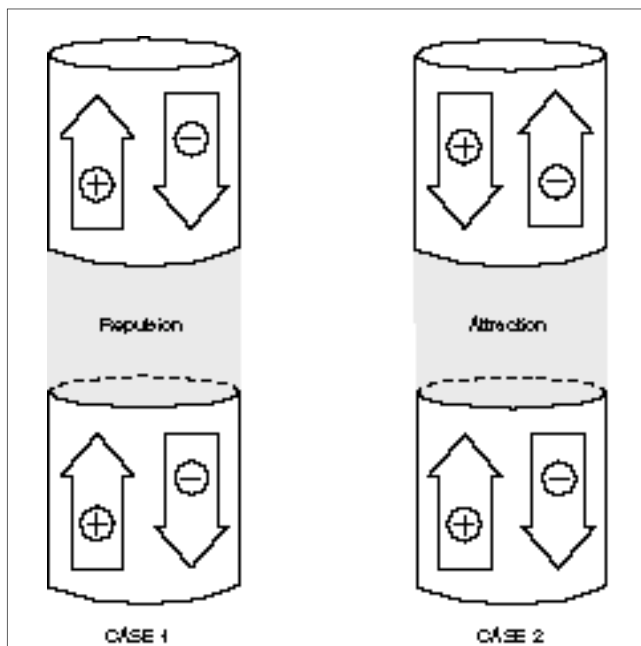


Figure 6
WEBER'S DEVELOPMENT OF AMPÈRE'S LAW:
LONGITUDINAL ELEMENTS

To broaden Ampère's approach to include the new phenomena of induction, Weber used the hypothesis of Gustav Fechner that a current consists of the opposite flow of positive and negative electrical particles. In this view, a single current element contains a positive and a negative particle in opposite motion, depicted here by the contents of a single cylindrical section of the wire. The schematic, for each case, depicts two of these current elements, one following the other, in a straight line along the wire. In Case 1, where the current elements (positive and negative particles for Weber) are moving in the same direction, Ampère's theory deduced repulsion. For Case 2, where the positive particles and the negative particles have opposite motion, Ampère deduced attraction. From these experimental deductions of Ampère, Weber determined the velocity dependency of the law of force between electrical particles.

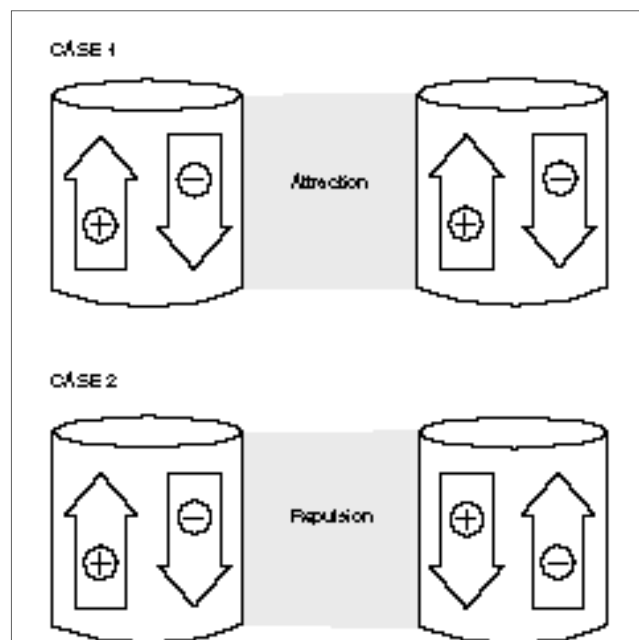


Figure 7
WEBER'S DEVELOPMENT OF AMPÈRE'S LAW:
PARALLEL ELEMENTS

When the current elements are parallel, Ampère's theory describes attraction in Case 1, where both elements move in the same direction, and repulsion in Case 2, where the two elements move in opposite directions. Weber noted that like electrical particles move in the same direction in Case 1, and in opposite directions in Case 2. In the longitudinal case, the same relative motions of the particles produced opposite results. Weber saw that in the parallel case, the relative velocity of the particles was zero, but that they had a relative acceleration. Thus came the acceleration term in his fundamental law of electricity.

velocity of all the electrical particles is zero, and thus the law just deduced can have no bearing in explaining the resultant force. That is, two particles approaching each other, are said to have a negative relative velocity; as their paths cross, their relative velocity is zero; as they now recede from each other, their relative velocity becomes positive. At the point of crossing, the relative velocity is changing from negative to positive. A change in relative velocity is known as *relative acceleration*. Thus at the instant under consideration, when the current elements are directly opposite each other, they have a *relative acceleration*, but no *relative velocity*.

Now, in Case 1 of Figure 7, where the net effect according to Ampère's experiments is attraction, we observe that it is the *unlike* particles that are in relative motion between the two current elements. In Case 2, where the force between current elements is repulsive, we observe that it is the *like* particles which are in relative motion. Thus the situation is the opposite of that noted for longitudinal current elements, and, rather than diminishing, the electrostatic force must be increased by the presence of a relative acceleration between particles. Thus must Weber add a term to the expression derived just above, which yields:

$$\frac{ee'}{r^2} \left(1 - a^2 \frac{dr^2}{dt^2} + b \frac{d^2r}{dt^2} \right), \quad \text{Eq. 2}$$

where b is also a constant to be determined.

Now a more detailed consideration arises; namely, unlike the previous case, the particles in parallel current elements do not move along the same straight line. When the function of their distance of separation is determined (Weber 1846, §19), the result is that

$$\frac{d^2r}{dt^2} = \frac{1}{r} \frac{dr^2}{dt^2}.$$

Hence, Equation 2 becomes:

$$\frac{ee'}{r^2} \left(1 - a^2 \frac{dr^2}{dt^2} + \frac{b}{r} \frac{dr^2}{dt^2} \right). \quad \text{Eq. 2(a)}$$

To find the relationship between the coefficients a and b , Weber returns once more to Ampère's work, and specifically to the point referenced in Gauss's 19 March letter. The ratio of the coefficients in Equation 2(a) is nothing other than the ratio of the force between parallel current elements to the force between longitudinal elements; namely the same relationship which Ampère had determined to have the absolute value $1/2$. Weber consequently sets:

$$a^2 = \frac{1}{2} \frac{b}{r}, \text{ or } b = 2a^2 r,$$

from which the general expression for the force between two electrical particles becomes:

$$\frac{ee'}{r^2} \left(1 - a^2 \frac{dr^2}{dt^2} + 2a^2 \cdot r \frac{d^2r}{dt^2} \right). \quad \text{Eq. 3}$$

By consideration of the four interrelationships existing among the particles of each pair of current elements, Weber divides

the constant a by 4, producing the finished 1846 form of his expression for the force between two electrical particles in motion:

$$\frac{ee'}{r^2} \left(1 - \frac{a^2}{16} \frac{dr^2}{dt^2} + \frac{a^2}{8} r \frac{d^2r}{dt^2} \right). \quad \text{Eq. 4}$$

This is Weber's fundamental law of electrical action as presented in his famous 1846 memoir, in which he also shows its application to the phenomenon of induction and its complete compatibility with Ampère's law. Most of the features of atomic physics that Weber was later to discover are already implicit in the formulation stated in Equation 4.

4. The Final Steps

In 1855, Weber and Rudolf Kohlrausch carried out experiments which determined with fine precision the value of the constant so far designated as a . They found that $4/a = 4.395 \times 10^{11}$ mm/sec, and this value, thenceforth designated c , came to be known as the *Weber constant*.² Weber understood the constant c as "that relative velocity which electrical masses e and e' have and must retain, if they are not to act on each other at all" (Weber and Kohlrausch 1856, p. 20). His fundamental law was from now on to be written:

$$\frac{ee'}{r^2} \left(1 - \frac{1}{c^2} \frac{dr^2}{dt^2} + \frac{2r}{c^2} \frac{ddr}{dt^2} \right). \quad \text{Eq. 5}$$

In a comment appended to the précis of the experiment, published jointly with Kohlrausch in 1856, Weber hints at the direction his thought was to take in coming years. Weber pointed out that the extremely small value of the coefficient $1/c^2$

makes it possible to grasp, why the electrodynamic effect of electrical masses . . . compared with the electrostatic . . . always seems infinitesimally small, so that in general the former only remains significant, when as in galvanic currents, the electrostatic forces completely cancel each other in virtue of the neutralization of the positive and negative electricity [Weber and Kohlrausch 1856, p. 21].

It shall shortly become clear that Weber was already groping for a means to penetrate to the level of the forces among these tiny particles of electrical charge, those which we now call *atomic*. His comment reveals that he could not see an experimental path to that goal. The power of his subsequent work resides largely in his determined working through of the theoretical implications of his earlier work.

Catalytic Forces and a Fundamental Length

We jump now to 1870, when Weber is under a sustained attack by Helmholtz and Clausius in Germany and Thomson, Tait, and Maxwell in Britain. They are claiming that Weber's law must violate the principle of conservation of energy. Helmholtz has constructed a specific case where, he claims, Weber's law will produce an infinite *vis viva*.

In a treatise which appeared in January 1871, his sixth memoir under the series titled "Electrodynamic Determinations of

Measure" (Weber 1871), Weber not only offers a devastating reply to the criticisms, but also discovers, purely through a theoretical analysis of his fundamental electrical law, basic principles of atomic physics, which were not empirically determined until decades later. In the opening pages of the memoir is found perhaps the most astounding of these discoveries, Weber's determination of a minimal distance below which the Coulomb force, the repulsion of like particles, must reverse and become attractive.

First Weber notes that the positive and negative electrical particles, expressed as e and e' , are not masses in the mechanical sense. Lacking our current use of the term, *charge*, they had been called at the time *electrical masses*. Weber draws the distinction, between charge and mechanical mass, expressing the former by e , and the latter by ϵ (epsilon). He then recognizes that while the amount of charge on positive and negative electrical particles is equal, though opposite, their masses need not be equal. He thus arrives for the first time, on page 3 of the *Sixth Memoir*, at the modern concepts of charge-to-mass ratio and proton-electron mass ratio.

Weber next examines an underlying assumption in his fundamental law of electrical action. Namely, that the expression for the force, which the particles, e and e' , mutually exert upon each other, is dependent on a magnitude, that is, their relative acceleration, "which contains as a factor the very force that is to be determined." He makes this clear by the consideration that the relative acceleration must consist of two parts—one due to the mutual action of the two particles, and a second part due to other causes. The second part would include whatever velocity the particles may have in directions other than the line r connecting them, and whatever is due to the action on them by other bodies. He had already considered this aspect of the matter in the 1846 memoir (p. 212 ff.), where he employs the term *catalytic forces* to describe them, after the expression introduced by the chemist Berzelius. In that location, by considering separately the mathematical term for the force of acceleration which each one of the particles exerts on the other one, he was able to derive an expression for his fundamental law which is independent of the acceleration term caused by their mutual action, but which still must contain a term, f , which denotes the acceleration due to other causes. The expression thus derived is

$$\frac{ee'}{rr - \frac{2r}{cc}(e + e')} \left(1 - \frac{1}{cc} \frac{dr^2}{dt^2} + \frac{2rf}{cc} \right). \quad \text{Eq. 6(a)}$$

But when the distinction is made between the charge (e, e') and the mass (ϵ, ϵ') of the electrical particles, Weber shows in the *Sixth Memoir* (Weber 1871, pp. 2-6) that the expression then becomes:



Chris Lewis

Jonathan Tennenbaum observing the ultra-sensitive receiving apparatus of the Gauss-Weber telegraph, set up here to detect very weak magnetic forces. The telegraph, the world's first, was constructed in 1833, and ran from the Göttingen Observatory to the Physics Building.

$$\frac{ee'}{rr - \frac{2r}{cc} \frac{\epsilon + \epsilon'}{\epsilon\epsilon'} ee'} \left(1 - \frac{1}{cc} \frac{dr^2}{dt^2} + \frac{2rf}{cc} \right). \quad \text{Eq. 6(b)}$$

"From this it results," Weber remarks, "that the law of electrical force is by no means so simple as we expect a fundamental law to be; on the contrary, it appears in two respects to be particularly complex." The first complexity is the *catalytic forces* just referenced. The second is the appearance of a unique length, associated with reversal of the Coulomb force. As Weber describes that latter aspect of the discovery:

In the second place, another noteworthy result follows from this expression for the force—namely, that when the particles e and e' are of the same kind, *they do not by any means always repel each other*; thus when $dr^2/dt^2 < cc + 2rf$, they repel only so long as

$$r > \frac{2}{cc} \frac{\epsilon + \epsilon'}{\epsilon\epsilon'} ee',$$

and, on the contrary, they attract when

$$r < \frac{2}{cc} \frac{\epsilon + \epsilon'}{\epsilon\epsilon'} ee'.$$

This remarkable result is no more than a necessary, mathematical consequence of the expression for Weber's fundamental law just given above. It is easily seen that when e and e' represent two similar particles, the expression gives $4e^2/\epsilon c^2$. Recalling that the Weber constant is $2 \times$ the velocity of light, we have then in modern terms, where c expresses the velocity of light, and m_e the mass of the electron, the familiar expression

Critics of Ampère and Weber

Ampère's revolutionary hypothesis that magnetism arises from electrical orbits surrounding the particles of matter became the basis for the development of early atomic science by Gauss, Weber, and others. But many could not understand his hypothesis, nor deal with the fact that its mathematical development implied an overthrow of Newtonian mechanics.

Among the leading critics of Ampère and Weber's work were Hermann Grassmann, James C. Maxwell, and the English engineer Oliver Heaviside. Grassmann attacked the Ampère hypothesis as "improbable," but without giving a reason. Maxwell took the middle ground of allowing Ampère's hypothesis, but rejecting Weber's development of it. Heaviside's position is notable as an expression of the sort of gross empiricism so frequently encountered in science today. His suggestion, that Ampère's contribution be changed to what it was not, has been adopted by most modern textbooks.



Hermann Grassmann
(1809-1877)

When I submitted the explanation offered by Ampère for the interaction of two infinitely small current-sections on one another to a more exacting analysis, this explanation seemed to me a highly improbable one. . . .

—Hermann Grassmann,
*A New Theory of
Electrodynamics*, 1845

There are also objections to making any ultimate forces in nature depend on the velocity of the bodies between which they act. If the forces in nature are to be reduced to forces acting between particles, the principle of the Conservation



Millikan and Gale, *A First Course in
Physics* (Boston: Ginn & Co. 1915)
James Clerk Maxwell
(1831-1879)

of Force requires that these forces should be in the line joining the particles and functions of the distance only.

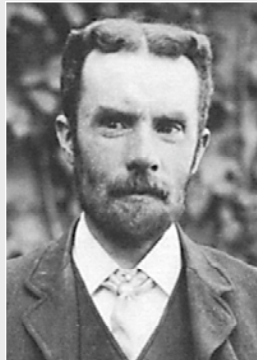
—James Clerk Maxwell,
On Faraday's Lines of Force,
1854

It has been stated, on no less authority than that of the great Maxwell, that Ampère's law of force between a pair of current elements is the cardinal formula of electrodynamics. If so, should we not be always using it? Do we ever use it? Did Maxwell in his Treatise? Surely there is some mis-

take. I do not in the least mean to rob Ampère of the credit of being the father of electrodynamics: I would only transfer the name of cardinal formula to another due to him,

expressing the mechanical force on an element of a conductor supporting current in any magnetic field—the vector product of current and induction. There is something real about it; it is not like his force between a pair of unclosed elements; it is fundamental; and, as everybody knows, it is in continual use, either actually or virtually (through electromotive force), both by theorists and practitioners.

—Oliver Heaviside,
in *The Electrician*, 1888



IEE Archives
Oliver Heaviside
(1850-1925)

$$\frac{2e^2}{m_e c^2}.$$

That is the distance below which two electrons may not approach, which, when divided by two, gives the classical electron radius of 2.8×10^{-13} cm. When the mass of the proton is inserted into the Weber expression, the value 3.06×10^{-16} cm results—perhaps some sort of lower bounding value for the strong force, in any case, a most interesting approximation for the year 1870!

Weber's 1871 paper progresses in richness. The laws of motion of an electron orbiting around a central nucleus are deduced, and the determination that two like particles cannot have such orbital motion, but that an oscillation along the

same line (as if attached by a rubber band) is possible. (From this latter, Weber attempts to find the basis for the production of oscillations of the frequency of light.) Finally, Helmholtz's silly charge that the electrical particles will attain an *infinite energy* under Weber's formulation, is answered with the observation that Helmholtz assumes the possibility of the particles also attaining *infinite relative velocities*. Rather it is the case, Weber points out, that his constant, c , must represent a *limiting velocity* for the electrical particles.

These are some of the remarkable results produced by that singular intervention of Gauss in his letter of 19 March 1845. His recognition of the *real existence* of a mere *idea*, which had appeared in the mind of Ampère by no later than 1823, led to the discovery of some of the most crucial among the concepts of our modern physics. Thus did a scientific *idea*, a

colorless, odorless, and tasteless substance, change the course of history.

Yet, none of these remarkable accomplishments of the line of work from Ampère to Gauss to Weber, which we have just reviewed, is recognized in the standard histories, or textbooks today. Only when one delves into the remote corners of specialist sources can scant mention of these facts be found—always presented as isolated events, never with coherence. How can it be that the names of Ampère, Gauss, and Weber are never mentioned when the physics of the atom is taught? If the name of Ampère arises, it is in connection only with electricity and magnetism. The actual law of electrical force he discovered is almost impossible to find in any modern textbook; under Ampère's name appears something quite different. The name of Weber is rarely heard.

Today, students of physics and electrical engineering are taught that all of the laws of electrodynamics have been included under the ingenious formulations arrived at by James Clerk Maxwell and codified in his 1873 *Treatise on Electricity and Magnetism*. One need not study Ampère and Weber, they are told, because Maxwell already did that. He also did us the service of cleaning up any "errors" that might have been found there. And a very thorough job it was.³

But where, pray tell, did the method of discovery go? Or is that no longer of interest to students today? Is it that we know so much today, that it would only be confusing to teach how we know it? (Some might even be so foolish as to argue thusly.) Yet not just the method is missing. So too are its results. Where did the classical electron radius, the nuclear strong force, the limiting value of the velocity of light come from? Not from Ampère, Gauss, and Weber, according to today's textbooks and authorities. Did we in any way exaggerate when we used the term *a consumer fraud* to describe the university science education which commits such glaring omissions? Has a fraud been committed, a cover-up? Was it accidental or witting? We hope we have given the reader sufficient leads that he may investigate and decide for himself.

Laurence Hecht is an associate editor of 21st Century. A co-thinker of Lyndon H. LaRouche, he is currently a political prisoner in the state of Virginia.

Notes

1. The mathematical development of Ampère's hypothesis, of a force acting along the straight line connecting two elements, and certain uncritical references to Newton found in the opening pages of his 1826 Memoir, have emboldened some interpreters, Maxwell included, to falsely presume Ampère to be a Newtonian. They completely miss the point. Ampère's 1826 Memoir is rather a sort of Gödel's proof for experimental physics: working within the framework of Newtonian assumptions to demonstrate the absurdity of sticking to the Newtonian assumptions of point mass and a simply continuous, linear-extended space-time. Without referencing it explicitly, Ampère is raising precisely the same points of criticism of Newtonian assumptions addressed a century earlier by Gottfried W. Leibniz in his famous correspondence with Newton's proxy Samuel Clarke, and in his *Monadology*. Immediately following the completion of his 1826 Memoir on electrodynamics, Ampère turned his attention to these deeper implied issues of his experimental work, becoming a champion of Leibniz's method in science from that time until his death in 1836.

The continuing hegemony within mathematical physics, even to the present moment, of Leonhard Euler's fraud respecting Leibniz's work, is the root of the failure of Maxwell and all subsequent specialists to recognize this essential aspect of Ampère's contribution. Where science must answer such questions by experimental measurement, Euler claims to re-

fute Leibniz's insistence on the existence of atomic structure within the "hard, massy particles" of Newton's cosmology, by resorting in his *Lettres to a German Princess*, to a blackboard trick. To defend the existence of a mere mathematical construct, his ever-present infinite series, Euler claims to prove the *physical existence* of a simply continuous space-time by successively subdividing a straight line into as many parts as the mind can imagine ("as near as you please" in Augustin Cauchy's more refined version of the ruse). Thus is reality stood on its head by a mathematician's trick, passed on from generation to credulous generation of university science undergraduates.

See also, Lyndon H. LaRouche, Jr., "Riemann Refutes Euler," *21st Century Science & Technology*, (Winter 1995-1996) pp. 36-47.

2. The experiment actually determined the ratio of the mechanical measure of current intensity to the three other existing measures, that is, the electromagnetic, the electrodynamic, and the electrolytic. The value given above, the *Weber constant*, is the ratio of the mechanical to the electrodynamic measure. Weber first showed in 1846 that the ratio of the electrodynamic to the electromagnetic unit is as $\sqrt{2}:1$. Therefore, the experimentally derived ratio of the mechanical measure of current intensity to the electromagnetic measure was 3.1074×10^{11} mm/sec. Bernhard Riemann, who observed the Weber-Kohlrausch experiment, was the first to note that the value corresponded closely to Fizeau's experimental determination of the velocity of light. His theory of *retarded potential* proceeded from there. Here Riemann attempted the unsolved task of which Gauss had commented in the 19 March 1845 letter:

Without a doubt, I would have made my investigations public long ago, had it not been the case that at the point where I broke off, what I considered to be the actual keystone was lacking . . . namely, the *derivation* of the additional forces (which enter into the reciprocal action of electrical particles at rest, if they are in relative motion) from the action which is *not instantaneous*, but on the contrary (in a way comparable to light) propagates itself in time.

3. Maxwell was a capable mathematical analyst and possessed a creative gift for physical-geometrical insight. His utter ignorance of matters of method, which took the form of a slavish adherence to the method of empiricism, prevented his ever understanding the deeper issues posed by Gauss above (note 2). Maxwell stubbornly remarks on Gauss's challenge:

Now we are unable to conceive of a propagation in time, except either as the flight of a material substance through space, or as the propagation of a condition of motion or stress in a medium already existing in space [*Treatise*, p. 492].

Maxwell's dismissal of what he did not understand, increasingly took on the character of ignorant prejudice. There was nothing original in his idea of an ether as the transmitting medium of electromagnetic action. Had Gauss seen a clear solution through such a mode of representation, he would have developed it. There was none, as the glaring failure of Maxwell's theory to even account for the existence of the electron ought to indicate.

References

- André-Marie Ampère, 1826. "Memoire sur la théorie mathématique des phénomènes électrodynamiques uniquement déduite de l'expérience," in A.M. Ampère, *Electrodynamiques, uniquement déduite de l'expérience* (Paris: A. Hermann, 1883). A partial English translation appears in R.A.R. Tricker, *Early Electrodynamics: The First Law of Circulation* (New York: Pergamon, 1965) pp. 155-200.
- James Clerk Maxwell, 1873. *A Treatise on Electricity and Magnetism*, Vols. 1 and 2 (New York: Dover, 1954) Unabridged Third Edition. Wilhelm Eduard Weber, 1846. "Elektrodynamische Maassbestimmungen über ein allgemeines Grundgesetz der elektrischen Wirkung," in *Wilhelm Webers Werke* (Berlin: Julius Springer, 1893) Vol. 3, pp. 25-214. Unpublished English translation by Susan P. Johnson.
- Wilhelm Eduard Weber and R. Kohlrausch, 1856. "Über die Elektrizitätsmenge, welche bei galvanischen Strömen durch den Querschnitt der Kette fliesst," *Annalen der Physik und Chemie, herausgegeben von J.C. Poggendorff*, Vol. 99, pp. 10-25. Unpublished English translation by Susan P. Johnson.
- Wilhelm Eduard Weber, 1871. "Elektrodynamische Maassbestimmungen, insbesondere über das Princip der Erhaltung der Energie," *Abhandlungen der mathem.-phys. Classe der Königl. Sächsischen Gesellschaft der Wissenschaften*, Vol. X (Jan.). English translation in *Philosophical Magazine*, 4th Series. Vol. 43, No. 283, January 1872, pp. 1-20, 119-49 ("Electrodynamic Measurements—Sixth Memoir, relating specifically to the Principle of the Conservation of Energy").

Experimental Apparatus and Instrumentation

1. The Gauss Magnetometer

Carl Friedrich Gauss's 1832 determination of the absolute intensity of the Earth's magnetic force was the crucial prerequisite for Weber's electrodynamic studies. Prior to Gauss's work, measurements of the intensity of the Earth's magnetic force were carried out by observing the oscillations of compass needles at varying points on the Earth's surface. Based on the theory of the pendulum, the intensity was assumed to be equal to the square of the number of oscillations.

Observations of both the horizontal and vertical (inclination and dip) intensity had been carried out sporadically over the previous century and brought to a high state of refinement by the travels of Alexander von Humboldt. But all of these observations contained an inherent weakness: that the magnetic strength of the needles used had to be considered equal and unchanging. A more exact determination of the magnetic intensity at differing points on the Earth's surface had long been desired for a better understanding of geomagnetism, which would be useful in navigation, surveying, and the Earth sciences. It was soon to play a crucial role as well in the theoretical pursuit of electrodynamics and atomic theory.

The problem in all the observations carried out prior to Gauss's work, was that the strength, or *magnetic moment*, M ,

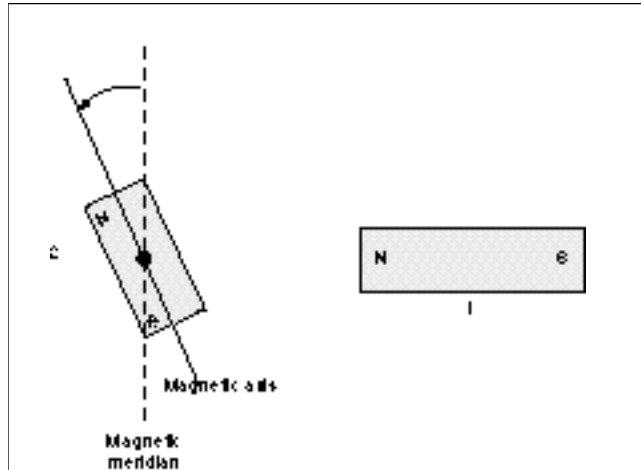
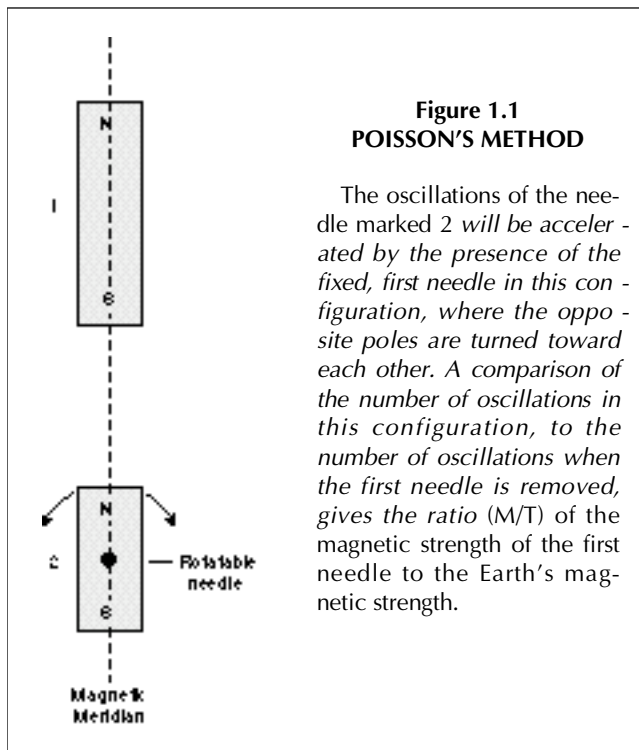


**Figure 1.2
GAUSS'S METHOD**

*Observations carried out by Poisson's method either totally miscarried, or produced very approximate results. In this configuration, conceived by Gauss, needle 1 tends to produce an angular deflection in the second, oscillating needle, while the Earth's magnetism attempts to return the second needle into a line with the magnetic meridian. The resulting angular deflection is proportional to the sought-for ratio M/T . An additional apparatus devised by Gauss, known as the *Spiegel und Fernrohr* (mirror and telescope), allowed for the precise determination of the angular deflection to a hitherto unknown degree of accuracy. (See Figure 1.3).*

of the oscillating needle could not be separated from the strength of the Earth's magnetism, T . The number of oscillations observed is proportional to the product of the two, MT . Thus, it is impossible to tell whether variations measured at different points on the Earth's surface, or at different times in the same location, represent changes in the intensity of the Earth's magnetism, or are a result of a natural weakening of the needle's magnetism.

Before Gauss, Poisson in France had suggested a means of overcoming this obstacle, by making a second set of observations on the compass needle whose oscillations, under the influence of the Earth's magnetic force, had already been observed. Poisson proposed to fix this needle in line with the magnetic meridian (that is, pointing to magnetic north). A second, rotatable or oscillating needle was then to be placed in the same line (Figure 1.1).

The oscillations of the second needle would be either retarded or accelerated by the presence of the first needle, according to whether like or unlike poles are turned toward

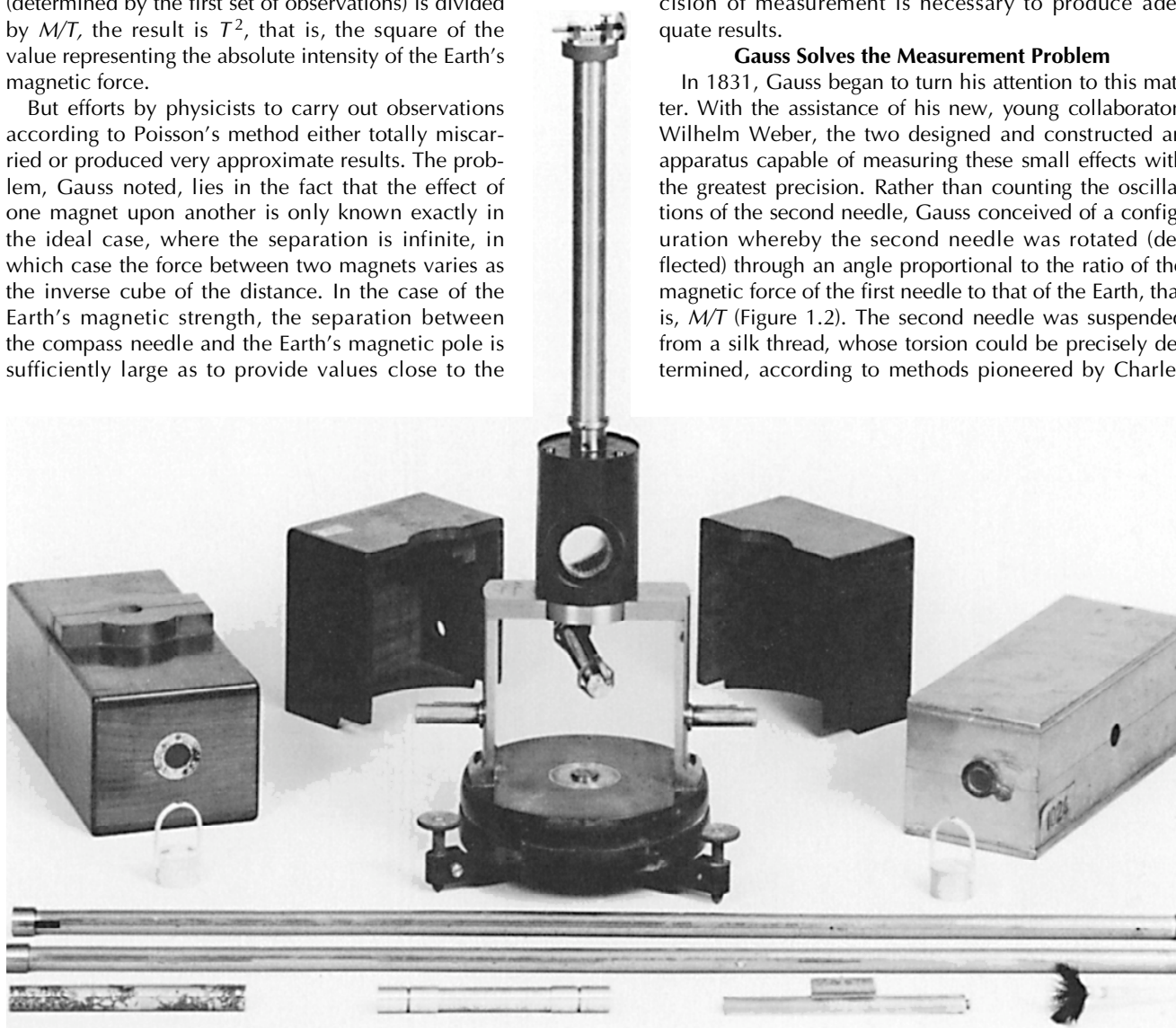
each other. By comparing the number of oscillations of the second needle when in the presence of the first one, to its oscillations when standing alone (that is, under the sole influence of the Earth's magnetic force), the ratio M/T , expressing the strength of the first needle to the magnetic strength of the Earth, could be determined. When the value of MT (determined by the first set of observations) is divided by M/T , the result is T^2 , that is, the square of the value representing the absolute intensity of the Earth's magnetic force.

But efforts by physicists to carry out observations according to Poisson's method either totally miscarried or produced very approximate results. The problem, Gauss noted, lies in the fact that the effect of one magnet upon another is only known exactly in the ideal case, where the separation is infinite, in which case the force between two magnets varies as the inverse cube of the distance. In the case of the Earth's magnetic strength, the separation between the compass needle and the Earth's magnetic pole is sufficiently large as to provide values close to the

ideal case. However, to carry out the second observation on two compass needles of finite separation—as suggested by Poisson—with any degree of accuracy, requires that the separation distance of the two needles be rather large in relation to the length of the second one. This means that the observable effect is very small, and therefore the greatest precision of measurement is necessary to produce adequate results.

Gauss Solves the Measurement Problem

In 1831, Gauss began to turn his attention to this matter. With the assistance of his new, young collaborator, Wilhelm Weber, the two designed and constructed an apparatus capable of measuring these small effects with the greatest precision. Rather than counting the oscillations of the second needle, Gauss conceived of a configuration whereby the second needle was rotated (deflected) through an angle proportional to the ratio of the magnetic force of the first needle to that of the Earth, that is, M/T (Figure 1.2). The second needle was suspended from a silk thread, whose torsion could be precisely determined, according to methods pioneered by Charles



Historical Collection of the Göttingen University I. Physical Institute

A transportable magnetometer built for Wilhelm Weber in 1839 by Meyerstein. The apparatus in the center is used to determine the absolute intensity of the Earth's magnetic force. In the first row, in foreground, are two bar magnets with cleaning brush and holder. Behind it are two brass bars which can be attached to the magnetometer housing at either of the two flanges seen protruding to the left and right. The bar magnet, which plays the role of needle 1 in the schematic of Figure 1.3, is slid along this non-magnetic brass support until the proper distance is achieved.

Suspended in the center of the magnetometer housing is a rotatable carrier holding the cylindrical magnetized needle, which plays the role of needle 2 in Figure 1.3. The rotatable carrier is suspended by two silk threads which run up the vertical column to the highest point of the apparatus (44 cm). Attached to the carrier is a plane mirror, which is observed through the porthole in the dark cylindrical casing above the rotatable magnet. A telescope and meter stick such as that pictured on page 23 would be aimed at the mirror.

The boxes, at far left and right, hold weights used to determine the gravitational moment of the magnet. In the background are a wooden housing to protect the apparatus from air currents and a copper one for damping the oscillations of the needle with electrical current.

Augustin Coulomb in France, several decades earlier. Then, through an ingenious apparatus conceived by Gauss, the angle of deflection could be measured with a degree of precision hitherto unknown.

Gauss's angle measurement apparatus, the *Spiegel und Fernrohr* (mirror and telescope), was integrated into many types of precision measuring instruments well into this century. Figure 1.3 schematically portrays one of the earliest versions of the apparatus. In later versions, the mirror was attached at the rotational axis of a carrier holding the second compass needle, or magnet (see photograph of 1839 device, page 36). Another important breakthrough, also incorporated into the pictured 1839 device, was the development of the *bifilar* (two-thread) suspension. By varying the distance of separation of the two parallel silk threads supporting the rotatable compass needle, their torsion could be adjusted with the greatest precision. Since the torsion provided a part of the restoring force, against which the angular rotation of the second needle by the first had to operate, its exact determination was essential for experimental accuracy.

Gauss's 1831-1832 study of magnetism, reported in his paper "The Intensity of the Earth's Magnetic Force Reduced to Absolute Measure,"¹ became the model for all rigorous investigation thereafter. The study included the first introduction of the concept that the units of *mass*, *length*, and *time* could serve as the basis for all physical measurement.

Notes

1. "Intensitas vis magneticae terrestis ad mensuram absolutam revocata," read by Gauss at the Göttingen Gesellschaft der Wissenschaften on 15 December 1832, and printed in Volume 8 of the treatises of this society, pp. 3-44.

German translation from the original Latin, by Dr. Kiel of Bonn, available as: *Die Intensität der Erdmagnetischen Kraft auf absolutes Maass zurückgeführt* (Leipzig: Wilhelm Engelmann Verlag, 1894).

English translation (unpublished) from the German, by Susan P. Johnson.



Chris Lewis

The boxed portable magnetometer, on display in the Historical Collection of the Göttingen University I. Physical Institute.

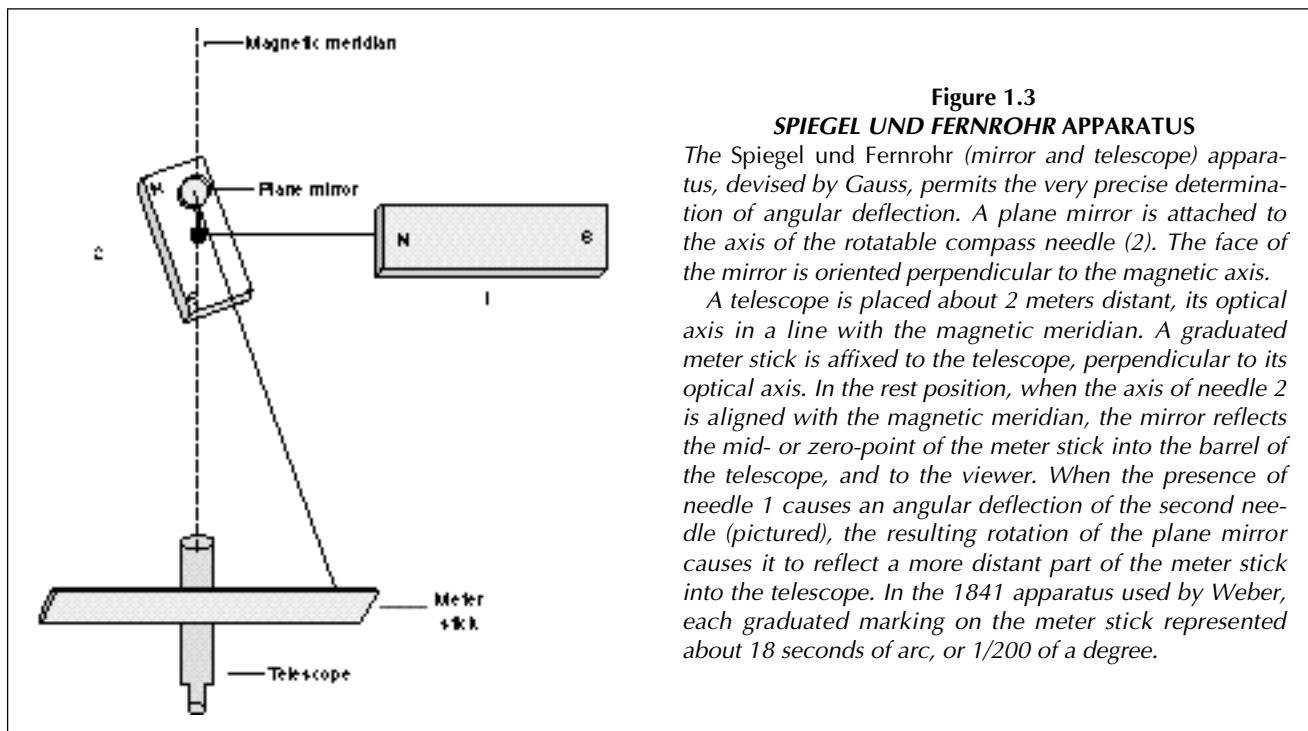


Figure 1.3

SPIEGEL UND FERNROHR APPARATUS

The Spiegel und Fernrohr (mirror and telescope) apparatus, devised by Gauss, permits the very precise determination of angular deflection. A plane mirror is attached to the axis of the rotatable compass needle (2). The face of the mirror is oriented perpendicular to the magnetic axis.

A telescope is placed about 2 meters distant, its optical axis in a line with the magnetic meridian. A graduated meter stick is affixed to the telescope, perpendicular to its optical axis. In the rest position, when the axis of needle 2 is aligned with the magnetic meridian, the mirror reflects the mid- or zero-point of the meter stick into the barrel of the telescope, and to the viewer. When the presence of needle 1 causes an angular deflection of the second needle (pictured), the resulting rotation of the plane mirror causes it to reflect a more distant part of the meter stick into the telescope. In the 1841 apparatus used by Weber, each graduated marking on the meter stick represented about 18 seconds of arc, or 1/200 of a degree.

2. The Electrodynamometer and Weber's Proof of Ampère's Theory

Commenting in 1846, on the state of electrical science since the 1826 publication of Ampère's famous memoir on electrodynamics, Wilhelm Weber wrote:

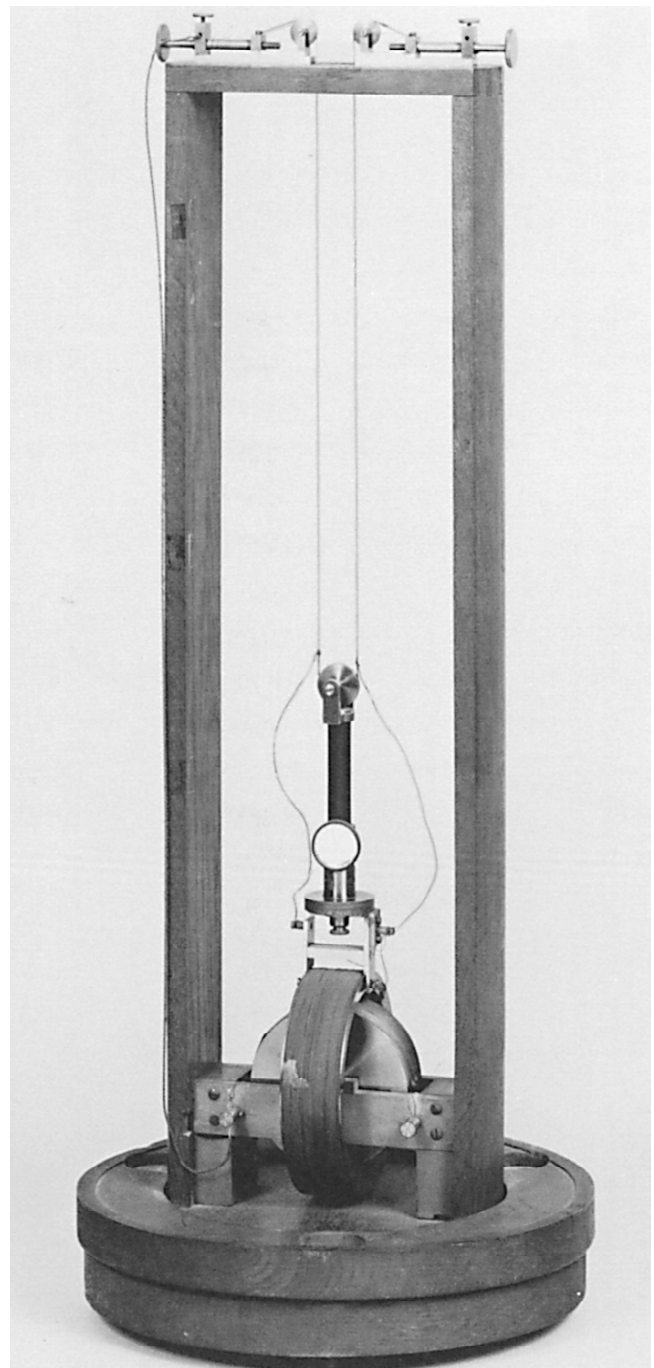
Ampère did not continue these investigations, nor has anyone else published anything to date, from either the experimental or theoretical side, concerning further investigations. . . . This neglect of electrodynamics since Ampère is not to be considered a consequence of attributing less importance to the fundamental phenomenon discovered by Ampère . . . but rather it results from dread of the great difficulty of the experiments, which are very hard to carry out with present equipment. . . . [Weber 1846, Introduction]

The essential problem Weber saw with Ampère's apparatus was the possibility that the force of *friction* might be disguising subtle effects. In each of Ampère's equilibrium experiments, deductions are made from the lack of motion of a movable conductor, for example, the rectangular conductor CDGH in the second equilibrium experiment (Figure 4 in article text). If this lack of motion were the result, even in small part, of frictional resistance, then the entire set of deductions derived by Ampère would have to be re-evaluated.

To establish the validity of Ampère's theory with more exactness, it was necessary to devise an apparatus in which the electrodynamic forces were strengthened, such that friction would be only a negligible fraction of the force measured. This was the purpose of the instrument, known as the electrodynamometer, the first model of which Weber constructed in 1834.

The essential improvement over Ampère's various apparatuses was, that instead of single wires interacting with each other, a pair of multiply wound coils was used. This had the advantage that each successive winding would multiply the effect of the electrodynamic force between the two coils. Thus, even the smallest currents flowing through the coils could produce measurable effects. But the use of coils, rather than single lengths of wires, would require a completely different experimental geometry. And, rather than attempting experiments whose purpose was to produce zero motion, Weber intended to precisely measure the rotational force exerted by one coil on another. Then, by geometric analysis, he would reduce these results to the effect of a single circular loop on another, and, through further analysis, relate the strength of this effect to that predicted by Ampère's law.

The principal elements of Weber's apparatus were two cylindrical coils of wire, called solenoids by Ampère. One cylinder was suspended horizontally such that it could rotate around a vertical axis. The other was placed horizontally in a fixed position, usually either perpendicular (Figure 2.1) or longitudinal to the first coil. We know from Ampère's earliest experiments, that when current passes through a solenoid, it takes on the properties of a bar magnet, one end of the cylinder acting as north pole, and the other as south. Thus, as can be seen from Figure 2.1, the arrangement of the Weber electrodynamometer



Historical Collection of Göttingen University I. Physical Institute

This is the electrodynamometer, constructed in 1841, which Weber used to experimentally verify Ampère's electrodynamic theory. The larger outer ring is the bifilar coil, so called because it is suspended from above by two wires, which also carry current to it. The inner ring, an electrical coil known as the multiplier, is affixed to a wooden frame with tripod base. During the experiment, the multiplier and frame are placed in various positions on the laboratory table to determine its rotational effect on the bifilar coil. The angle of rotation is measured by observing the mirror (affixed to the suspension apparatus) through a telescope with meter stick attached.



Chris Lewis

Professor G. Beuermann (r.) of Göttingen University demonstrates the sending apparatus of the 1833 electromagnetic telegraph of Gauss and Weber to Jonathan Tennenbaum. In the background is displayed part of the historical collection of Weber's apparatus.

is quite analogous to that of the Gauss magnetometer.

Weber borrowed the use of the bifilar (two-thread) suspension from this earlier instrument, but instead of silk threads, he used the conducting wires themselves to suspend the coil. Thus, a hollow wooden cylinder wound with insulated copper wire, which came to be known as the *bifilar coil*, was sus-

pended from above by its own two wire leads. The second cylindrical coil, known as the *multiplier*, was placed in the same horizontal plane, at right angles, or longitudinal to the first. A mirror was affixed to the bifilar coil, and its angle of rotation observed with a telescope and meter stick, just as in the magnetometer.

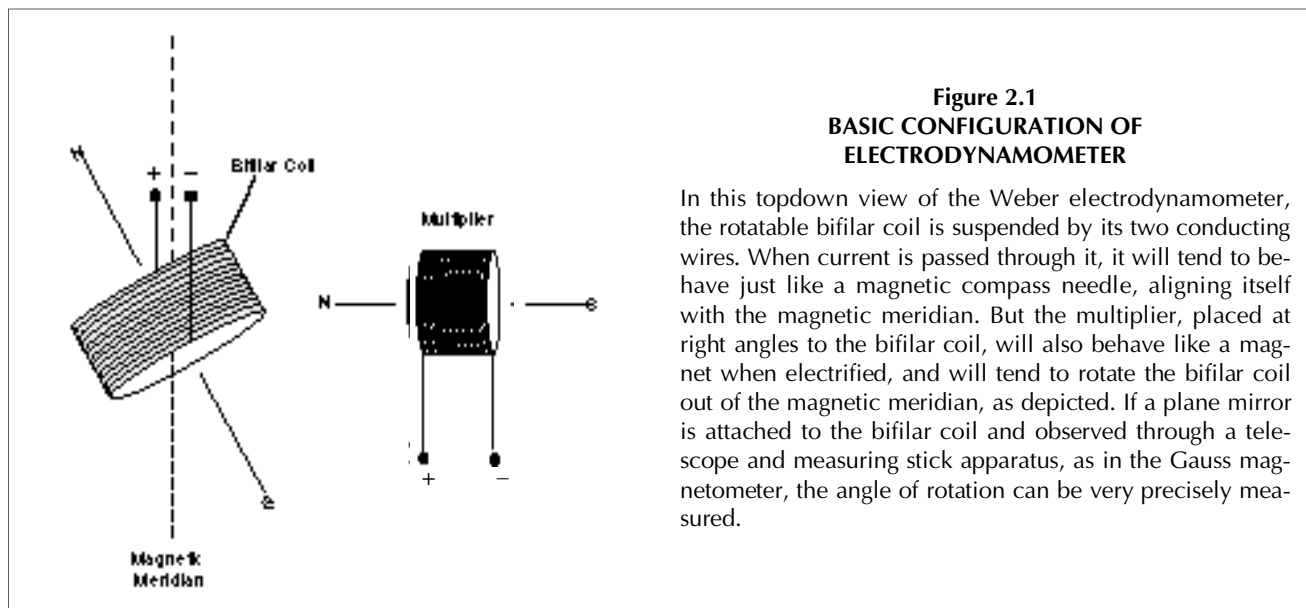


Figure 2.1
BASIC CONFIGURATION OF
ELECTRODYNAMOMETER

In this topdown view of the Weber electrodyndynamometer, the rotatable bifilar coil is suspended by its two conducting wires. When current is passed through it, it will tend to behave just like a magnetic compass needle, aligning itself with the magnetic meridian. But the multiplier, placed at right angles to the bifilar coil, will also behave like a magnet when electrified, and will tend to rotate the bifilar coil out of the magnetic meridian, as depicted. If a plane mirror is attached to the bifilar coil and observed through a telescope and measuring stick apparatus, as in the Gauss magnetometer, the angle of rotation can be very precisely measured.

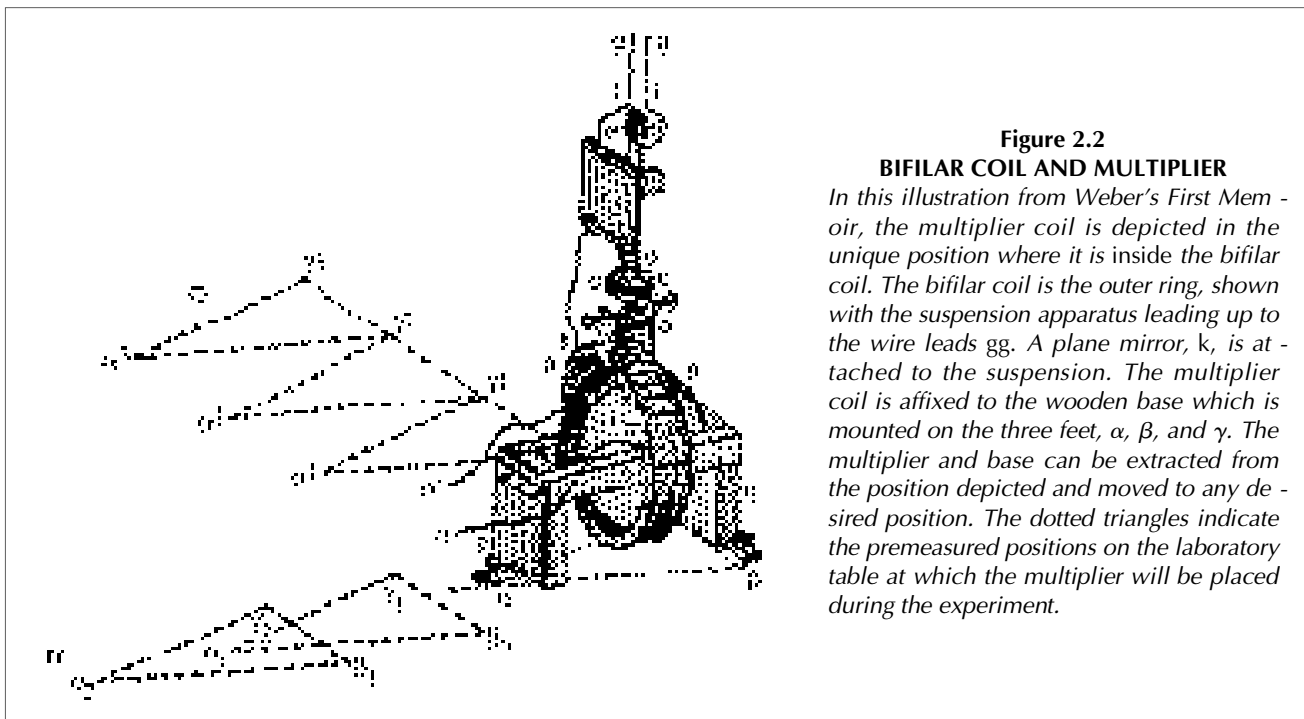


Figure 2.2
BIFILAR COIL AND MULTIPLIER

In this illustration from Weber's First Memoir, the multiplier coil is depicted in the unique position where it is inside the bifilar coil. The bifilar coil is the outer ring, shown with the suspension apparatus leading up to the wire leads gg. A plane mirror, k, is attached to the suspension. The multiplier coil is affixed to the wooden base which is mounted on the three feet, α , β , and γ . The multiplier and base can be extracted from the position depicted and moved to any desired position. The dotted triangles indicate the premeasured positions on the laboratory table at which the multiplier will be placed during the experiment.

After additional instrumentation was added to measure the precise current flow through each coil, observations were made with the multiplier positioned at varying, precisely measured distances to the east, west, north, and south of the bifilar coil (Figures 2.2, 2.3). A table of experimentally determined values was then arrived at, representing the torque, or rotational moment, exerted by the multiplier on the bifilar coil at the different distances. By knowing the number of turns in each coil, and by assuming from the symmetry of the windings, that the total effect could be considered as concentrated in the most central loop of each coil, Weber was then able to reduce these observed values to the mutual effect of a single pair of circular loops, acting at each measured position of the multiplier and bifilar coil.

In his mathematical theory of electrodynamics, Ampère had developed a formula that provided a theoretical determination of what the rotational moment of two such circular loops should be, dependent on their distance of separation, the area enclosed by each, their relative angles, and the strength of current flowing in them. Weber was now able to compare the predicted values, derived from Ampère's controversial theory of electrodynamics, to a set of experimentally determined values. The difference amounted to less than 1/3 of a scale unit (about 6 seconds of arc), of which Weber wrote in his First Memoir:

This complete agreement between the values calculated according to Ampère's formula and the observed values (namely, the differences never exceed the possible amount contributed by unavoidable observational error) is, under such diverse conditions, a full proof of the truth of Ampère's law [Weber 1846, §8].

—Laurence Hecht

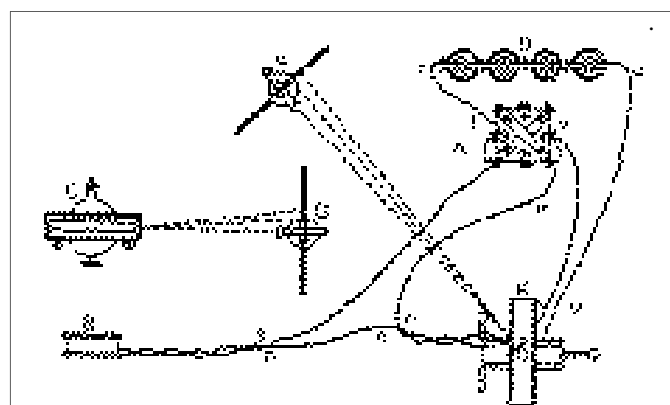
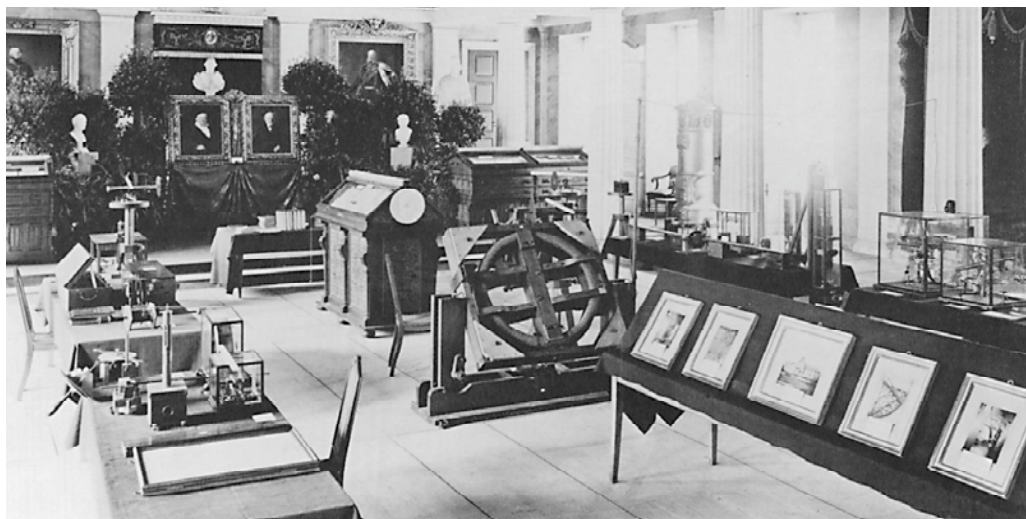


Figure 2.3
SCHEMATIC OF WEBER'S EXPERIMENT

In addition to the bifilar coil and multiplier, depicted in the closed position at E, this schematic diagram from Weber's First Memoir shows the other instrumentation required for the verification of Ampère's electrodynamic theory.

The telescope and meter stick for observing the rotation of the bifilar coil is shown at F. The current supply (a four-cell battery) is depicted at D and a commutator for reversing the direction of current flow at A. The apparatus at B, C, and G measures the current in the circuit and takes the place of a modern ammeter. B is a second multiplier coil connected to the main circuit, and about 20 feet distant from the bifilar coil. C is a portable magnetometer whose deflections (measured by the telescope and meter stick at G) correspond to the current strength in B. Observers were required at both the scopes F and G, to take simultaneous readings of the deflection of the bifilar coil and the current strength, and a third operator to manipulate the current supply.



An exhibit honoring Gauss and Weber in June 1899 at Göttingen University. Portraits of the scientists are surrounded by their experimental apparatus and illustrations of their experiments. On the tables at left are various electrical and magnetic apparatus. The large coil in the center mounted on a wooden dolly is from the Earth inductor, which can still be seen today in the Gauss House at Göttingen.

* * *

Weber to Gauss, No. 30, 1 February 1845

Highly honored Herr Hofrath:

I have just noticed, that in the manuscript I recently sent to you, there is apparently missing a note regarding Ampère's formula, which would be necessary in order to understand it. Namely, Ampère has given a more general expression, for the interaction of two current elements, than I introduce there, which I seek to justify, by means of the consideration that the empirically derived definition of the coefficient of the second term, which I have discarded, seems completely untrustworthy, because of the unreliability of the method, and hence that coefficient, so long as it lacks a more precise quantitative determination, by the same reasoning would have to be set = 0. If I am not in error, you yourself earlier expressed certain thoughts about discarding the negative value which Ampère assumed for that coefficient by means of which two current elements, one following the other, would have to mutually repel one another.

With heartfelt respect.

Leipzig, 1845, February 1

Your most devoted,
Wilhelm Weber

* * *

Gauss to Weber, 19 March 1845

Esteemed friend:

Since the beginning of this year, my time has been incessantly taken up and frittered away in so many ways, and on the other hand, the state of my health is so little favorable to sustained work, that up to now, I have not been in any position to go through the little treatise you were so good as to send me, and to which I just now have been able to give a first quick glance. This, however, has shown me that the subject belongs to the same investigations with which I very extensively occupied myself some 10 years ago (I mean especially in 1834-1836), and that in order to be able to express a thorough and exhaustive judgment upon your treatise, it does not

suffice to read through it, but I would have to first plunge into study of my own work from that period, which would require all the more time, since, in the course of a preliminary survey of papers, I have found only some fragmentary snatches, although probably many more will be extant, even if not in completely ordered form.

However, if, having been removed from that subject for several years, I may permit myself to express a judgment based on recollection, I would think, to begin with, that, were Ampère still living, he would decidedly protest, when you express Ampère's law by means of the formula

$$-\frac{\alpha\alpha'}{rr} ii' \sin\theta \sin\theta' \cos\epsilon \quad (I)$$

since that is contained in a wholly different formula, namely

$$-\frac{\alpha\alpha'}{rr} ii' \left(\frac{1}{2} \cos\theta \cos\theta' + \sin\theta \sin\theta' \cos\epsilon \right). \quad (II)^2$$

Nor do I believe that Ampère would be satisfied by the appended note, which you mention in a later letter, namely, where you cast the difference in such a way, that Ampère's formula would be a *more general one*, just like

$$-\frac{\alpha\alpha'}{rr} (F \cos\theta \cos\theta' + G \sin\theta \sin\theta' \cos\epsilon)$$

where Ampère experimentally derived $F = \frac{1}{2} G$, while, because Ampère's experiments may not be very exact, you think that with equal correctness, you can claim that $F = 0$. In any other case than the present one, I would concede that in this discordance between you and Ampère, a third party would perhaps clarify the matter as follows, that:

whether one (with you) views this as merely a modification of Ampère's law, or

whether (as, in my estimation, Ampère would have to view the matter), this is nothing less than a complete overturning of Ampère's formula, and the introduction of an essentially different one,

is at bottom little more than idle word-play. As I said, in any other case I would gladly grant this, since no one can be in

verbis facilius [more easy-going in matters of verbal formulation] than I. However, in the present case the difference is a vital question, for Ampère's entire theory of the interchangeability of magnetism with galvanic currents depends absolutely on the correctness of Formula II and is wholly lost, if another is chosen in its place.

I cannot contradict you, when you pronounce Ampère's experiments to be not very conclusive, while, since I do not have Ampère's classic treatise at hand, nor do I recall the manner of his experiments at all, nonetheless I do not believe that Ampère, even if he himself were to admit the incompleteness of his experiments, would authorize the adoption of an entirely different formula (I), whereby his entire theory would fall to pieces, so long as this other formula were not reinforced by *completely decisive* experiments. You must have misunderstood the reservations which, according to your second letter, I myself have expressed. Early on I was convinced, and continued to be so, that the above-mentioned interchangeability *necessarily* requires the Ampère formula, and allows no other which is not identical with that one for a closed current, *if the effect is to occur in the direction of the straight lines connecting the two current elements*; that, however, if one relinquishes the just-expressed condition, one can choose countless other forms, which for a closed current, must always give the same end result as Ampère's formula. Furthermore, one can also add that, since for this purpose it is always a matter of effects at measurable distances, nothing would prevent us from presupposing that other components might possibly enter into the formula, which are only effective at immeasurably small distances (as molecular attraction takes the place of gravitation), and that thereby, the difficulty of the repulsion of two successive elements of the same current could be removed.

In order to avert misunderstanding, I will further remark, that the Formula II above can also be written

$$-\frac{\alpha\alpha'}{rr}ii'\left(-\frac{1}{2}\cos\theta\cos\theta'+\sin\theta\sin\theta'\cos\epsilon\right)$$

and that I do not know, whether Ampère (whose memoir, as I said, I do not have at hand) used the first or the second notation. Both of them signify the same thing, and one uses the first form, when one measures the angle θ , θ' with the same delimited straight line; thus, this line determines the side of the second angle in the opposite way, but determines the other form, when one is considering a straight line of indeterminate length, and, for the measurement of angle θ , θ' , one resorts to that line twice, in one sense or another. And, likewise, one can place a + sign in front of the whole formula instead of the – sign, if one is considering as a positive effect, not repulsion, but attraction.

Perhaps I am in a position to again delve somewhat further into this subject, which has now grown so remote from me, by the time that you delight me with a visit, as you have given me hope that you will do at the end of April or the beginning of May. Without a doubt, I would have made my investigations public long ago, had it not been the case that at the point where I broke off, what I considered to be the actual keystone was lacking

Nil actum reputans si quid superesset agendum

[Discussions accomplish nothing, if work remains to be done]
namely, the *derivation* of the additional forces (which enter

into the reciprocal action of electrical particles at rest, if they are in relative motion) from the action which is *not instantanea*, but on the contrary (in a way comparable to light) propagates itself in time. At the time, I did not succeed; however, I recall enough of the investigation at the time, not to remain wholly without hope, that success could perhaps be attained later, although—if I remember correctly—with the subjective conviction, that it would first be necessary to make a constructible representation of the way in which the propagation occurs.

With hearty greetings to your brothers and sister and to Professor Möbius.

Göttingen, 19 March 1845

Ever yours,
C.F. Gauss

* * *

Weber to Gauss, No. 31, 31 March 1845

Highly honored Herr Hofrath:

Professor Buff from Giessen, who is travelling from here to Göttingen, in order to visit Woehler, his former colleague in Cassel, will have the goodness to bring you these pages. It has been of great interest to me to learn from what you were kind enough to write, that Ampère, in the definition of the coefficient he calls k in his fundamental law, was guided by other reasons, than the ones from immediate empirical experience which he cites at the beginning of his treatise, and that hence the derivation, which I first gave, because it seemed somewhat simpler, is inadmissible, because it does not reproduce Ampère's law with exactness; yet, by means of what seems to me to be a slight modification in my premise, I have easily obtained the exact expression of Ampère's law.

Through the interest taken in the matter, and through the encouragement of Fechner and later Möbius, I have been induced to occupy myself up to a point, with a subject which I conceived from the start might well be beyond me; I am all the happier that you are inclined to turn your attention once more to this arduous subject, and to give a complete development of it. Certainly, the explanation derived from a gradual propagation of the effect would be the most beautiful solution of the riddle. In response to your kind invitation, I will certainly not fail to come to Göttingen by the end of this spring.

In conformity with your instructions, I will send to the Royal Society in London a copy of the five last annual summaries of the *Resultate*, by way of the book dealer, since it will be difficult for me to pursue the invitation to Cambridge. Whence the Royal Society has obtained a copy of the first annual summary, I do not know, since they did not buy it.

Möbius, who is now celebrating his silver wedding anniversary, and my sister, remember themselves to you and your daughter with the greatest regard.

With the most heartfelt respect.

Leipzig, 1845, March 31

Your most devoted,
Wilhelm Weber

Notes

1. The title by which Weber addressed Gauss is approximately translated as "Mr. Court Councillor."
2. This seems to be Gauss's only error of memory: The epsilon should be an omega.

EDITORIAL

SHOULD THE LAW OF GRAVITY BE REPEALED?

The Suppressed Electrodynamics of Ampère-Gauss-Weber

From the Spring 2001 issue of *21st Century Science & Technology* (full text)

[The Ampère Angular Force](#)

[The Fundamental Electrical Law of Weber](#)

[The Weber Constant](#)

[Gravitation](#)

[Limiting Velocity and Critical Length](#)

[Notes](#)

An iron curtain divides the subjects of gravity and electrodynamics, in today's academically accepted versions of physics. Those attempting to cross it will risk the intellectual equivalent of machine-gun fire. Beyond, lie even more serious obstacles which come, not from outside, but from within the mind of the investigator. To get at the source of those self-imposed shackles, requires that we go beyond the bounds of what is today defined as "physics," into matters usually classified as philosophical, or metaphysical. In doing so, we cannot avoid noticing that there are two schools in physical science, each one so distinct from the other as to constitute two entirely different domains. It is the unfortunate aspect of our modern legacy that most, even among well-educated scientists, are unaware even of the existence of such a distinction. Yet, if the real history of physics of the 19th century were known, most of what passes as teaching of fundamental topics in that discipline today, would be shown to be, in the best of cases, misdirected, in the worst, willful fraud.

We know of no better way to correct this deficit than to present this review of the conceptual history of 19th Century electrodynamics. We have two purposes. First, to provide the reader with an introduction to the mostly unknown electrodynamic theory of André-Marie Ampère, and his successors—this, as a necessary aid to understanding our feature article on the subject of anti-gravity by the distinguished French research scientist, Dr. Rémi Saumont. Second, by exposing a crucial aspect of the suppressed history of gravity, electricity, and magnetism, to address the deeper problem of method holding back science today.

The heart of the matter before us, begins with the hypothesis and experimental validation of the Ampère angular force. Before the discovery by Oersted and Ampère of the effective equivalence of a closed current and a magnet, it appeared that the pairwise forces between bodies were governed by the same law of universal gravitation, which Johannes Kepler had first noted in his 1609 *New Astronomy*.¹ At the time in question, 1819-1821, three known phenomena appeared to behave according to the assumption that the force between two bodies was determined according to the inverse square of their distance of separation. Apart from gravitation, these were the phenomena of *electrostatic*, and *magnetic* attraction and repulsion, investigated especially by Coulomb and Poisson.

In all three cases, there was some question as to the perfect validity of the inverse-square assumption. In the case of magnetism, the impossibility of separating the two opposite poles, made exact measurement of the pairwise relationship of one magnet to another always inexact. This problem of the existence of a "third body" did not entirely go away, even in the case of the most carefully observed of these phenomena, gravitation.

The Ampère Angular Force

In 1826, André-Marie Ampère published a groundbreaking study, summarizing the work of five years of research into the laws of the new science that he had named *electrodynamics*. The results showed, that in the case of the pairwise interaction of two infinitesimally small elements of direct current electricity within conductors, the force between the elements was not simply dependent on the inverse square of their distance of separation, but also depended on the angles which these infinitesimal, directional elements made with the line connecting

their centers, and with each other. (Included among the effects of the angular force was the result that successive elements of current within the same conductor would tend to repel one another—the longitudinal force.)²

Ampère's discovery did not escape the attention of Carl Friedrich Gauss at Göttingen University, the foremost mathematical physicist of the age. Within two years of the publication of Ampère's results, Gauss turned his attention to the matter of firmly establishing their validity. His program, which was not to reach complete fruition until 1846, required, first, the establishment of an *absolute measure* for the force of the horizontal intensity of the Earth's magnetism (a measure of the deviation of the compass needle from true North). Up to that time, all measure of the strength of the Earth's magnetism was relative, determined by counting the frequency of vibration of a particular magnetic needle. Gauss, a masterful experimentalist as well as the leading mathematician of the age, determined to apply the precision techniques of astronomical measurement to the task. The result was the instrument known as the *magnetometer*. In his paper of 1832, Gauss created a revolution in geophysics, showing how to determine the Earth's magnetic force at any given location and time.³

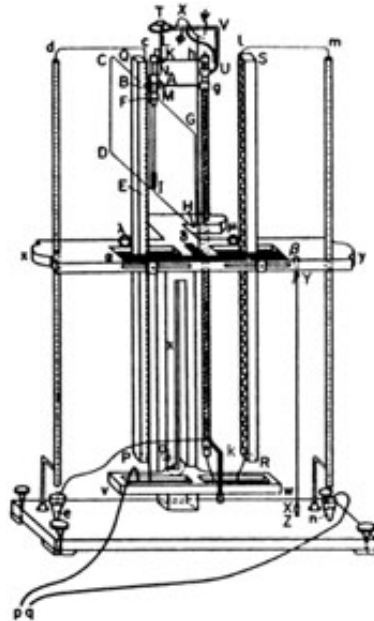
One methodological aspect of the paper on magnetism proved defining for physics to this day. As also for his later work with Wilhelm Weber, in connection with electrical measurement, Gauss determined that the measure of magnetic force must be consistent with the units of measure of *mass*, *length*, and *time*, already in use in other branches of physics. Owing to the philosophical and historical illiteracy of most contemporary physics teaching, however, Gauss's intention is nearly always misconstrued, to assume that these units are meant to be self-evident scalar quantities. Rather, as a familiarity with Gauss's immediately preceding work on the subject of curvature would show (and, as was made perfectly explicit in the famous 1854 *Habilitation* thesis of his leading student, Bernhard Riemann,⁴) Gauss had already introduced a fully *relativistic* conception into the framework of experimental physics. His 1828 description of the attempt to use state-of-the-art surveying techniques to measure the angular defect of a large terrestrial triangle should make this point evident⁵: As elaborated 26 years later by Riemann, it is the principal task of physics to determine the nature of the non-constant curvature of the non-Euclidean, multiply-connected geometric manifold which defines the action of physical processes.

We will shortly see how, in the joint work with Weber on the determination of the fundamental electrical law, Gauss again introduces an actually relativistic conception, this time in connection with the measure of force.

The reader must be warned, at this point, against a probable misinterpretation of the import of statements made so far: That would be to assume, that, were my perfectly accurate historical statements to be proven valid to his satisfaction, it would only be necessary to correct some names and dates to make the accounts in existing textbooks more or less valid. The reader's persisting error would involve, among other things, a confusion over our use of the term *relativistic*. From Kepler's rejection of a reductionist treatment of the inverse square law of gravitation discovered by him, through the work of Leibniz, Huygens, and the Bernoullis on the common isochronic principle governing falling bodies and light propagation in an atmosphere, to Gauss's devastating proof of Kepler's planetary harmonics, in his discovery of the orbit of Ceres, there prevailed a conception of the foundation of physics entirely different from that taught in today's respectable institutions of learning. Today, the term *relativistic*, means a formulaic correction to a system of equations and other formalisms premised on an assumed, self-evident notion of three-fold extension in space and one-fold in time. Up to, approximately, the 1881 seizure of power by Hermann von Helmholtz at Berlin University's Physics Department, the leading minds of European continental science rejected such an underlying assumption as sophomoric.

Again, the problem is present-day historical illiteracy. It is essential that the

reader grasp that the history we sketch here, is not some “alternative current” in physics. The early 19th Century discoveries, originating in Paris, and spreading into Germany through the influence of Gauss and his students at Göttingen University, were not some alternative current in physics. They remained, throughout most of the 19th century, the central line of thought. Today’s academically acceptable physics is built on a radical deviation from that line of thought, imposed, not by reason, but by political maneuverings. (Attempts to provide alternative explanation, rarely represent more than the sort of bureaucratic maneuvering which the advocate supposes to be necessary to maintain job and position.) The proximate source of the errors can be traced to the imposition of the Maxwell electrodynamics and the flawed doctrine of thermodynamics associated with Clausius and Helmholtz. The deeper differences go to the fraudulent representation of the Leibniz calculus by Euler and Maupertuis, and its effect in suppressing the earlier breakthroughs of the French Scientific Academy, as exemplified by the work of Huygens.



Ampère constructed many different electrical apparatuses to deduce the relationship of current elements that went into his angular-dependent force law. Here, a reproduction from his 1825 work of the Second Equilibrium Experiment, in which a movable conductor, GH, is suspended between parallel vertical beams, PQ and RS, one containing a straight wire, one a sinuous wire. The experiment shows that GH does not move when current passes through all the wires.

The Fundamental Electrical Law of Weber

The experimental validation of the Ampère force was accomplished over the period 1832-1846, by Gauss’s assistant and leading experimental collaborator, Wilhelm Weber. Weber’s discovery made a revolution in physics, the full implications of which are still unrealized. Worse, today, the underlying discovery itself is almost buried.

Ampère’s experimental conclusions drew on a series of brilliant geometrical deductions, derived from the observation of configurations of current-carrying wires in which the forces, presumably, cancelled each other, producing no observable motion. To validate the Ampère Law, one needed to be absolutely sure that the lack of motion was not due to friction in the joints of the apparatus, or related effects. Gauss and his young assistant, Wilhelm Weber, devised a new apparatus, the electrodynamicometer, which could directly measure, to within fractions of a second of arc, the angular displacement produced in a multiply wound electric coil by another electrical coil perpendicular to it. By reducing the effects of each of the two coils to that of circular current loops, Ampère’s simple law for the force exerted by a current loop could be applied. Placing the coils in different positions, and at different distances from each other, allowed for determinations of the electrodynamic force, geometrically equivalent to those which Ampère had deduced from his null experiments.

The results of a rigorous program of instrument building and experimentation, interrupted by Weber’s expulsion from Göttingen University as a result of the political events of 1837, were finally published at Leipzig in 1846.⁶ These results completely confirmed the deductions of Ampère, and also introduced a new physical principle.

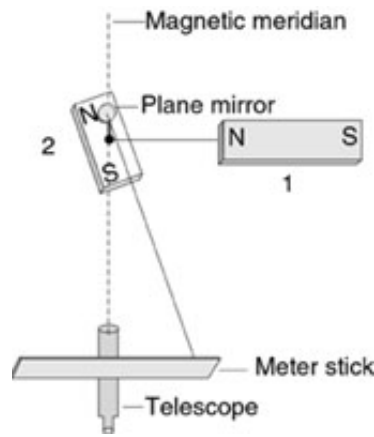
The discovery of the phenomena of electrical and magnetic induction had introduced a new element into the considerations of electrical law, not taken up in Ampère's 1826 work. There thus existed, side by side, three seemingly valid descriptions of the electrical interaction: (1) the Coulomb-Poisson law, describing the interaction of two electrical masses at rest; (2) the Ampère law, describing the interaction of elements of moving electricity, and: (3) a description of the laws of induction, elaborated by Emil Lenz and Franz Neumann. In his Fundamental Electrical Law, stated in 1846, Weber achieved the unification of these various phenomena under a single conception.

Instead of the mathematical entities, described as *current elements* by Ampère, Weber hypothesized the existence within the conductor of positive and negative electrical particles. He assumed that the presence of an electrical tension caused these particles to move at equal velocities in opposite directions. If one regards an Ampère current element as containing, at any given instant, a positive and a negative electrical particle, passing each other, then in the pairwise relationship of two current elements, there are four interactions to be considered. By the Coulomb law, these interactions, consisting of two repulsions and two attractions, cancel each other. However, the elementary experiments of Ampère had shown that a motion is produced between the wires, implying the existence of a force not described by the Coulomb law.

For example, two parallel conducting wires attract each other when the current in the two wires flows in the same direction, and repel each other when the opposite is the case. The situation is perfectly well explained under the Ampère force law, when one takes into account the angular relationship of the respective current elements. However, Weber's unifying approach was to assume that the relative velocities of the electrical particles produced a modification in the Coulomb electrostatic force, to produce the resultant force between the wires. Considering all the configurations which Ampère had examined, as well as those arising from the phenomena of induction, he was able to formulate a general statement of the Fundamental Electrical Law. This showed that the general law describing the force of interaction of two electrical particles, depends upon the relative velocities and the relative accelerations of the particles.⁷ The Coulomb electrostatic law thus becomes a special case of Weber's general law, when the particles are at relative rest.

It is not too difficult to see that Weber's Fundamental Electrical Law, almost unknown today, is a statement of a relativistic law of physics, long predating the statement of relativity we are accustomed to.⁸ Here it is the *force*, rather than the *mass*, which varies with the relative motion. But, not only does it predate the Einstein formulation, it is methodologically far superior. One can, in various ways, attempt to show an equivalence of the two statements, but the usefulness of such efforts is doubtful. The problem lies elsewhere. The two statements lie in two entirely different domains. One is a continuation of the Leibnizian current of physics; the other, whatever the intentions, serves to hide errors embedded in the assumptions underlying the Maxwell equations.

Left, a schematic diagram of the magnetometer designed by Carl Friedrich Gauss in 1831, to measure, for the first time, the absolute intensity of the Earth's magnetic force. Needle 1 tends to produce an angular deflection in the second, oscillating needle, while the Earth's magnetism attempts to realign it with the magnetic meridian. The resulting deflection is measured by reflection of



the meter stick into the telescope. By comparing this deflection of needle 2 to the oscillation of the same needle, when acting solely under the influence of the Earth's magnetism, the absolute intensity of the magnetic force is determined.

At right is a portable magnetometer built for Wilhelm Weber in 1839.



The Weber Constant

In the Weber Electrical Law, there is a relative velocity, corresponding to the constant c in his formula, at which the force between a pair of electrical particles becomes zero. The Weber-Kohlrausch experiment, carried out at Göttingen in 1854, was designed to determine this value. It was found to be experimentally equal, in electrodynamic units, to the product of the velocity of light, *in vacuo*, with the square root of 2. That value, became known as the *Weber constant*. In electromagnetic units, it was equal to the light velocity. Bernhard Riemann, who participated in the experiment, soon wrote up the obvious conclusion of a deep connection between light and electrodynamic, or electromagnetic phenomena. What was not obvious, was the answer to a question which Gauss had insisted, in his 1845 correspondence with Weber, be a prerequisite to further progress. That was to find a *constructible representation* of how the propagation of the electrodynamic interaction occurs.⁹

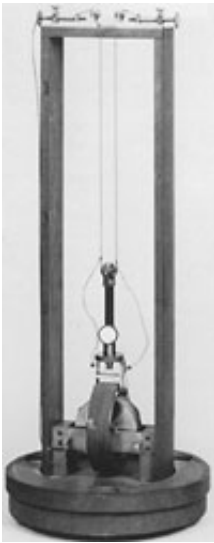
What Maxwell is famously celebrated for, unifying the representation of light and electromagnetic phenomena using a wave conception, was precisely what Gauss—and Ampère before him, had rejected as an oversimplification. Ampère had been so close to the development of the modern wave theory of light, that its founder, his good friend Augustin Fresnel, lived in his Paris apartment at the same time that Ampère was carrying out his electrical researches. To suppose that Ampère, and later Gauss, did not consider a wave representation for electromagnetic propagation is absurd. In order to establish his theory, Maxwell had to disregard the most crucial questions and anomalies that had arisen in the decades-long study of these phenomena by the greatest minds before him. Foremost among these were the angular (or relative velocity) dependency of the electrodynamic force, and the little problem of where gravitation should fit in.

Gravitation

The possibility of subsuming the phenomenon of gravitation under electrodynamics, came up for serious discussion early in this history. One of the more widely discussed contributions was a memoir of about 1830 by O.F.

Mossotti, a French physics teacher at the University of Buenos Aires.¹⁰

Mossotti proposed to account for gravitation in the following way: If matter is assumed to be constituted of equal amounts of positive and negative electricity, then, by the usual interpretation, there would be a cancellation of the attractive and repulsive forces. However, if it be assumed that the attractive forces between particles of opposite electrical charge, slightly exceed the repulsive forces of the like particles, a universal tendency for attraction would result.



Historical Collection of
Göttingen University I.
Physical Institute

The electro-dynamometer, constructed in 1841, which Wilhelm Weber used in the final determination of the validity of Ampère's electrodynamics. It consists of two perpendicular electrical coils. The outer coil is suspended in such a way that its rotation, under the influence of the inner coil, can be precisely determined by observing the deflection of the mirror image of a meter stick in a telescope, as in the Gauss-designed magnetometer. The inner coil can be removed, and placed at various distances.

Weber gave serious consideration to the Mossotti hypothesis. In a posthumously published manuscript on the relationship of electricity and gravitation, he discussed the extreme difficulty of experimentally determining whether such a small difference between attractive and repulsive forces exists.¹¹

In the same memoir, Weber reviews the work of several astronomers, who attempted to apply his Fundamental Electrical Law to correct the law of gravitation, by including terms for the relative velocities and relative accelerations of a pair of bodies. One of the glaring anomalies in the Newton-Laplace theory of gravitation was its inability to accurately predict the advance of the perihelion of the planets, of which Mercury's is the largest. (The phenomenon is famous as being one of the foundational proofs for general relativity.)

In 1864, the Göttingen astronomer C. Seegers proposed to examine the advance of the perihelion from the standpoint that the gravitational force be represented in the same way as the Fundamental Electrical Law.¹² Thus, the relative velocities and accelerations of the bodies of the solar system would have to be taken into account, and the factor $1/c^2$ introduced as a correction. Eight years later, Prof. Scheibner in Leipzig determined a secular variation of 6.73 arc-seconds for the perihelion of Mercury, attributable to the application of the Weber law. In 1872, Tisserand found the value 6.28 seconds for Mercury, and 1.32 seconds for Venus, by applying the Weber law.¹³

Another approach to the unification of gravitation with the Ampère-Gauss-Weber electrodynamics, was taken at the beginning of the 20th Century by the Swiss mathematical physicist, Walther Ritz. After brilliant successes in spectroscopy at Göttingen, Ritz launched an attack on the electrodynamics of Maxwell and Lorentz, and attempted to revive the abandoned approach of Gauss, Weber, and Riemann. In a short paper on gravitation, he suggested that the net effect of the electrodynamic forces between two electrically neutral bodies would be an attraction. His approach was not that of Mossotti; rather, he seems to be considering the internal motions of the electrical particles in the atoms as generating such a net effect. The paper is all too short; Ritz died in 1909 at the age of 31. (Deviations in the gravitational force, detected at eclipses, and other anomalous effects suggesting the need for radical revamping of accepted theory continue to make themselves known. The recent work of Maurice Allais, Benedetto Soldano, and Shu-wen Zhou is notable.¹⁴)

Ritz was not alone in his dissatisfaction with the oversimplification of the Maxwell electrodynamics. From the first 1820 breakthrough hypothesizing the origin of magnetism in microscopic electrical currents, the Ampère electrodynamics was seen as a means of gaining insight into the microphysical domain. The enormously complex task of adducing the atomic structure from such indirect evidence as that provided by spectroscopy, came to an abrupt, abnormal halt about the time of the 1927 Solvay conference, where Bohr's great oversimplification of atomic structure was imposed by political thuggery of the worst sort. Here again, we come to the importance of a virtually unknown aspect of Weber's work.

Limiting Velocity and Critical Length

As for electrodynamics, so for the history of atomic theory, the modern teaching is largely a fairy tale. A brief look at two crucial matters will establish this point beyond contradiction, and may help orient the reader to finding a way out of the present impasse. If it appears, at first, that we have "dug him in deeper," by making matters more complicated than they might have already seemed, we are confident the feeling will be only temporary.

The point here is best summarized by reference to the last two of the memoirs, published in Weber's lifetime, under the title *Elektrodynamische Maassbestimmungen* (Determinations of Electrodynamical Measure). The 1870 memoir, available in English, was the first to come to this writer's attention,

about a decade ago.¹⁵ The immediate topic is Helmholtz's objection, that Weber's Electrical Law could lead to the possibility of infinite work arising from a finite amount of work. Weber shows that for Helmholtz's fears to be realized, electrical particles would have to move at enormous relative velocities, exceeding the constant c . He thus arrives at a concept of a limiting velocity, quite similar to that found 35 years later in the Special Theory of Relativity, yet arrived at by an entirely different process than that which leads Einstein to this assumption. (Again, the usual warnings apply: Any attempt to find an equivalence or interpolation, as by algebraic means, between the Ampère-Gauss-Weber electrodynamics, and today's Brand X, is fruitless. To achieve any useful understanding, the reader must relive the original discovery as if it were his own).

More startling than the immediate answer to Helmholtz's objection, are the conclusions Weber is led to in his preliminary summary of the Fundamental Electrical Law. Here, he introduces for the first time the consideration that the electrical particles possess not merely a quantity of electricity (the magnitude we today call *charge*), but also *mass*. When the consideration of mass is introduced into his velocity-dependent electrical force equation, it results that there is a *critical length* below which the force of repulsion between two electrical particles is changed to attraction, and vice versa! The Weber critical length has the value:

$$\frac{2}{cc} = \frac{ee'}{e+e'} ee'$$

where e and e' are the electrical quantity (charge) of the two particles, e and e' the masses, and c the Weber constant.

It is among the delightful ironies of the official cover-up known as modern scientific historiography, that the expression for the classical electron radius (a concept which is not supposed to come into existence for another 30 or more years), falls out of Weber's expression—indeed, as a trivial case!

It gets more interesting. Weber has already dared, in the 1870 paper, to conceive the notion we know today as the proton-electron mass ratio, which leads him to wonder as to the possible motions of the different configurations of particle pairs. It turns out that, according to his relativistic electrical law (one which was never considered in the accepted, modern formulations of atomic theory), it is possible to develop an orbital system for the case of a lighter electrical particle of one sign, orbiting a heavier particle of the opposite sign! It is also possible for two similar particles of the same sign to develop a closed system of oscillations along the straight line connecting them.

We leave to a future time, the treatment of the last major accomplishment of Weber, the refutation of Clausius' thermodynamics and the Helmholtz Energy Principle.¹⁶ The problem with the fraud known as modern, academically accepted science, is not merely that credit has not been given for these prior discoveries. Far more devastating is that, in the modern formulation of notions similar to those that Weber had derived far earlier, there is no lawful derivation. We fly, rather, by the seat of our pants, hoping to reach the destination intact.

—Laurence Hecht

Notes

1. Johannes Kepler, *New Astronomy*, William Donahue, transl. (Cambridge: The University Press, 1992) p. 395

2. André-Marie Ampère, "Memoire sur la théorie mathématique des phénomènes électrodynamiques uniquement déduite de l'expérience," in A.M. Ampère, *Electrodynamiques, uniquement déduite de l'expérience*, (Paris: A. Hermann, 1883). A partial English translation appears in R.A.R. Tricker, *Early Electrodynamics: The First Law of Circulation* (New York: Pergamon, 1965) pp. 155-200. "A review of the Ampère-Gauss-Weber electrodynamics appears in Laurence Hecht, "The Atomic Science Textbooks Don't Teach," *21st Century*, Fall 1996, pp. 21-43.

The law of force which Ampère derives is:

$$F = \frac{ii' ds ds' (\sin\theta \sin\theta' \cos\omega - \frac{1}{2} \cos\theta \cos\theta')}{r^2}$$

where ds, ds' are the current elements of intensities i, i' , r the distance connecting their centers, θ and θ' the angles which r makes with them, and ω the angle they make with each other.

3. Carl Friedrich Gauss, *Die Intensität der Erdmagnetischen Kraft auf absolutes Maass zurückgeführt*, ed E. Dom, *Ostwald's Klassiker der Exakten Wissenschaften*, Vol. 53 (Leipzig: Wilhelm Engelmann, 1894). English translation in *21st Century Science* archive (The Intensity of the Earth's Magnetic Force, Reduced to Absolute Measure).

4. Bernhard Riemann, "On the Hypotheses Which Lie at the Foundations of Geometry," in David Eugene Smith, ed., *A Source Book in Mathematics* (New York: Dover Publications, 1959) pp. 411-425.

5. Carl Friedrich Gauss, *General Investigations of Curved Surfaces*, transl. Adam Hiltebeitel and James Morehead (Hewlett, N.Y.: Raven Press)

6. Wilhelm Weber, "Elektrodynamische Maassbestimmungen: über ein allgemeines Grundgesetz der elektrischen Wirkung," *Werke* (Berlin: Julius Springer, 1893) Bd. 3, pp. 25-214. English translation in *21st Century Science* archive (Determinations of Electrodynamical Measure: Concerning a Fundamental General Law of Electrical Action).

$$7. F = \frac{ee'}{r^2} \left(1 - \frac{1}{c^2} \cdot \frac{dr^2}{dt^2} + \frac{2r}{c} \cdot \frac{d^2r}{dt^2} \right)$$

8. More than a decade before the publication of Weber's 1846 paper, one can find an 1835 entry in Gauss's Notebooks, showing a hypothesized form of the electrodynamic force law, dependent on relative velocity and acceleration, that is essentially equivalent to that which Weber used in the 1846 publication. Interestingly, the Gauss formulation appears on the same page as an alternative formulation, which was the one James Clerk Maxwell chose to use in his text *Treatise on Electricity and Magnetism* to falsely imply a difference in electrodynamic views among the three collaborators, Gauss, Weber, and Riemann.

c. "Text of the Gauss-Weber 1845 Correspondence," (in "The Atomic Science Textbooks Don't Teach,") *21st Century*, Fall 1996, pp. 41-43.

10. O.F. Mossotti, "On the Forces which Regulate the Internal Constitution of Bodies," in R. Taylor, ed. *Scientific Memoirs*, Vol. 1, pp. 448-469.

11. Wilhelm Weber, "Elektrodynamische Maassbestimmungen, insbesondere über den Zusammenhang des elektrischen Grundgesetzes mit dem Gravitationsgesetze," *Werke* (Berlin: Springer, 1894), Bd. 4, pp. 479-525. English translation in *21st Century* archive, (Determinations of Electrodynamical Measure: Particularly in Respect to the Connection of the Fundamental Laws of Electricity with the Law of Gravitation).

12. C. Seegers, "De motu perturbationibusque planetarum secundum legem electrodynamicum Weberianam solem ambientium," Göttingen, 1864

13. Tisserand, "Sur le mouvement des planètes autour du Soleil d'après la loi électrodynamique de Weber," *Compt. rend.* Sept. 30, 1872.

14. Maurice Allais, "Should the Laws of Gravitation Be Reconsidered," *21st Century*, Fall 1998, pp. 21-33. Benedetto Soldano, "Space Probe Acceleration Anomalies Suggest Nonequivalence," *21st Century*, Summer 1999, pp. 66-69, 75. 'hu-wen Zhou, "Abnormal Physical Phenomena Observed When the Sun, Moon, and Earth Are Aligned," *21st Century*, Fall 1999, pp. 55-61.

15. Wilhelm Weber, "Elektrodynamische Maassbestimmungen, insbesondere über das Princip der Erhaltung der Energie," (1871), *Werke* (Berlin: Springer, 1894), Bd. 4, pp. 247-299. English translation in *Philosophical Magazine*, 4th series, Vol. 43, No. 283, January 1872, pp. 1-20, 119-149 ("Electrodynamical Measurements—Sixth Memoir, relating specifically to the Principle of the Conservation of Energy").

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16. Wilhelm Weber, "Electrodynamische Maassbestimmungen, insbesondere über die Energie der Wechselwirkung," *Werke*, Bd. 4, pp. 362-412.

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FIRST ENGLISH TRANSLATION OF WEBER 1846 TREATISE

The Ampère Angular Force And the Newton Hoax

by Laurence Hecht

The Internet posting by *21st Century Science & Technology* of the first English translation of Wilhelm Weber's historic 1846 treatise on electrodynamics,^[1] raises anew the crucial question which could not be effectively addressed by any of the principal characters in a scientific battle that raged nearly two centuries ago. No true appreciation of the fundamental laws which lie at the basis of our modern physical science can be had, without first recognizing the manifold ways in which the imposition of the Anglo-Dutch financial institution's hoax, known as Isaac Newton, has infected modern science. Achieving clarity on this question is of urgent importance. For example, the currently fashionable package of environmental frauds, including Al Gore's climate hoax, and the injection of statistical methods into science generally, could never have been taken seriously by any scientist trained in classical methods.

The importance of Weber's work in electrodynamics was first brought to our attention by Manhattan Project physicist and physical chemist Dr. Robert J. Moon, designer of the Chicago cyclotron and a crucial figure in the development of the first atomic pile and the first plutonium reactor at the Hanford reservation. The implications of Weber's work for the present include the discovery of far more efficient paths to nuclear fusion, utilizing least action pathways determined by the nuclear geometry. Hence the several-fold importance of the appearance of this translation at this time.

The Weber, or more properly, Gauss-Weber electrodynamics, arose as an attempt to establish the validity of a crucial discovery of fundamental principle by France's André-Marie Ampère over the period of 1820-26. To appreciate the significance of Ampère's breakthrough, and the subsequent work of Germany's Carl Friedrich Gauss and Wilhelm Weber, a certain deeply embedded misconception resulting from the widespread promotion of the Newton hoax must be briefly addressed. Contrary to popular myths regarding the history of science, all competent fundamental investigation in modern science derives from the unique resolution of the paradox of knowability developed by Cardinal Nicholas of Cusa in his 1440 *On Learned Ignorance*, and the associated reforms in social policy embodied in the Council of Florence, as the case of Johannes Kepler's revolution in astronomy sufficiently illustrates. Yet, today that proven method of scientific advance has been virtually buried, except as it persists as an inchoate impulse within the actually human spirit. (The rapidly maturing work of the LaRouche Youth Movement's "basement" research teams is the happy exception which holds the promise of reversing that otherwise civilization-destroying trend.)

We owe this destruction of the scientific method to the success of Fra

Paolo Sarpi's (1552-1623) New Venetian Party operation, in finding a way to permit a limited progress in science, for reasons of state, while virtually outlawing any examination of the philosophical-epistemological issues on which fundamental discovery in science rests. That method, which became the state policy of the extended Anglo-Dutch financial empire from the late 17th Century onward, is conveniently identified as the Newton hoax, the immediate work product of Venice's Antonio Conti. By the time of the work in question, a virtual cult of Isaac Newton adulation, including salons and special "ladies' editions" of Newton's philosophy, had overtaken France and was weighing heavily upon the rest of Europe.

The Ampère Revolution

Ampère's revolution in science was completed by 1825 and published in 1826 as his *Memoire sur la théorie mathématique des phénomènes électrodynamiques uniquement déduite de l'expérience*^[2] (Memoir on the Mathematical Theory of Electrodynamical Phenomena Uniquely Deduced from Experiment). Ampère showed therein that the restatement of Kepler's discovery of the principle of universal gravitation, as associated with the name of Newton, could not possibly apply as a universal law, once the newly discovered phenomena of galvanic currents (persisting direct current, as opposed to the static discharge investigated by Franklin) were taken into account. Specifically, Ampère showed that the attempt to reduce the laws of nature to an interaction of self-evident particles obeying an inverse square law of attraction could not hold in respect to electrical currents. In that case, taking the infinitesimal element of current as the presumed self-evident existent, it turns out that the laws of interaction must be modified to take into consideration the angular direction of the current flow. Thus, the simple inverse square law gives way to a term embodying the sine and cosine of the angles which each member of a pair of infinitesimal current elements make with the line connecting their centers (See **Figure 1**).

While Ampère's discovery might appear today as a merely mathematical artifact, it must be understood that Ampère had presented his discovery within the prevailing formalism of "laws of force" with the obvious intention of challenging the Newtonian orthodoxy. The Newtonians of his day were not mistaken in their visceral dislike for Ampère's innovation. While Jean-Baptiste Biot and most of the physics establishment in France rejected the work, as a member of the Academy, Ampère was nonetheless officially honored for his discovery. Yet, within several years, under the reign of Louis Philippe, demotion and assignment to a strenuous position as inspector of schools, under conditions of ill health, hastened his early death at the age of 62.

Elsewhere, Ampère's work was also under attack. Even before his 1826 publication, an anonymous pamphlet (later attributed to England's Michael Faraday) had circulated at a Paris physics conference, attacking the Ampère-Fresnel conception of the *magnetic molecule*. This was the hypothesis, widely accepted today, that magnetism is the result of the motion of microscopic electrical currents within the particles of matter. In Germany, Hermann Grassmann argued the impossibility of so "complicated" a phenomenon as the angular force. Hermann Helmholtz found it offensive that anyone should propose that nature might work on the basis of anything more complex than attraction and repulsion of elementary particles according to the inverse square law.

In James Clerk Maxwell's revision of electrodynamics, which was codified in an 1873 textbook, which is widely accepted today as the classic work on the subject, the Ampère angular force had disappeared. Maxwell accepts the argument that, as electrical currents only appear in complete circuits, any dependence of the force exerted by the individual current element upon the angular direction is eliminated in the totality,

when the vector sum of all the elements within the circuit are taken. By such means, all subtleties may be removed from Nature and Life—the "bottom line" for all thus becomes the proverbial "six-feet under."

Gauss's Intervention

What rescued 19th-Century physics from irrelevance respecting such matters, was Carl Friedrich Gauss's recognition of the extraordinary significance of Ampère's discovery. Even more than Ampère, Gauss suffered the oppression of the Sarpi-Newton cult, a condition which was exacerbated by his dependency since childhood upon the charity of the Duke of Brunswick and Hanoverian nobility. Gauss nonetheless resolved, by no later than 1828, to make the experimental proof of the Ampère angular force a central point of concentration. At the Assembly of the Society of German Scientists and Physicians, which took place in the Fall of 1828 in Berlin, Gauss was introduced to the young physicist Wilhelm Eduard Weber, a disciple of Ernst Chladni who had already distinguished himself through highly original studies in wave behavior and acoustics. Weber was awarded a professorship at Göttingen University in 1831, where an intense experimental collaboration with Gauss began. As Weber reports the work in the 1846 treatise, in order to prove Ampère's hypothesis, it was first necessary to find a means of positively measuring the effect of one current-carrying conductor upon another. All of Ampère's deductions derived from experiments in which no force was produced, sometimes called equilibrium, or *null* experiments. As Weber noted, it were possible that subtle forces were acting, which were masked by frictional or other effects within the apparatus.

However, in order to positively measure the sometimes small external forces exerted by the conductors, it was first necessary to discount the effects of the constantly varying magnetism of the Earth. A means of determining the absolute measure of the Earth's magnetic strength was thus required. Hence, the first collaboration, which bore fruit in less than two years, was directed to the design and construction of the bifilar magnetometer, an instrument which could resolve the ambiguities left by the previous measuring techniques. The paper reporting on this achievement is one of the landmarks in the history of experimental physics, which includes among its achievements, the first statement of a universal system of physical units known as the Gaussian system, and a preliminary formulation of what was to become known as Dirichlet's Principle.^[3]

In 1837, a crisis was provoked at Göttingen by the accession of Queen Victoria to the British throne, and the appointment, under Salic Law, of a male ruler of the Hanover territory formerly under direct British rule. Wilhelm Weber was among a group of professors known as the Göttingen Seven who were dismissed for their principled refusal to sign a loyalty oath to the new King Ernst Augustus. The famed philologists Jacob and Wilhelm Grimm, and Gauss's son-in-law, the orientalist Heinrich Ewald, were also in the group. Weber was able to continue his collaboration with Gauss from off campus for several years, by the help of an aid society established for the dismissed professors. By that time, the experimental work establishing the validity of the Ampère angular force had been largely completed.^[4]

Weber's Results

The chief apparatus, known as the electrodymanometer, was an adaptation of the bifilar magnetometer, employing two electrical coils in place of two bar magnets. Both apparatuses employed the precision angle-measuring technique, conceived by Gauss, in which angular deflection is observed by noting the image of a meter stick, placed atop

a terrestrial telescope, which has been reflected through a small mirror attached to the rotatable part of the apparatus.

Owing to his dislocation and reappointment to a professorship at Leipzig, it was not until 1845 that Weber was able to undertake a written presentation of the extended experimental collaboration with Gauss. As the preserved correspondence establishes, Weber was first inclined to give way to the prevailing academic climate and omit discussion of the angular force. A letter of reply from Gauss caused him to return to the original intention of their collaboration.^[5]

As with Ampère, Weber chose to present the results in the mathematical format of a force law, in this case as the force between pairs of electrical particles. On the suggestion of Gustav Fechner, the epistemological psychologist and student of the Zend Avesta who was later to influence Bernhard Riemann, Weber chose to represent current flow in a wire as the motion in opposite directions of oppositely charged electrical particles. By analysis of their relative velocities and accelerations, the anomaly expressed by Ampère as an angular term now appeared as a diminution in the force of attraction or repulsion due to relative motion. Taking into account the laws of induction, unknown to Ampère in 1826, Weber developed a universal expression for the electrical action, in which the static electric (Coulomb) forces were merely the degenerate case in which the relative motion has gone to zero.

Weber's results meant that there was some relative velocity at which the force of repulsion between oppositely charged electrical particles would fall to zero. Mathematically, this took the form of a constant within his expression for the force, and for the potential, between the particle pairs. That value was known throughout most of the 19th Century as the *Weber constant*. In a remarkable series of experiments which he carried out in 1855 upon his return to Göttingen University, the value of the Weber constant was found to be the product of the velocity of light times the square root of 2. The experiments, at which Riemann was an observer and sometime assistant, were conducted with Rudolf Kohlrausch.

That determination of a universal "speed limit," usually associated with Einstein's 1905 formulation of Special Relativity, was already implicit in entries in Gauss's notebooks dating to 1833, where Gauss had proposed the relativistic formulation of the electrodynamic law. Einstein's later formulation derived from his unique conception of the *relativity of simultaneity*, but unfortunately was formulated as an attempt to save the appearances of the Maxwellian formulation. Maxwell's rejection of the Ampère-Gauss-Weber work had by then become codified within the teaching of physics in Germany, thanks largely to the undermining efforts of Helmholtz.

The replacement of the Ampère-Gauss-Weber electrodynamics by the Maxwell formulations, is usually justified on the ground that it permitted the unification of electrical with optical phenomena, under the concept of electromagnetic waves. However, an examination of the 1845 Gauss-Weber correspondence shows that Gauss had already entertained the idea of electrical waves in the ether, but rejected it only on the grounds that a "constructible representation" of the phenomena was lacking. Riemann recognized the deep significance of the 1855 Weber-Kohlrausch experiments, and in an 1858 paper, "A Contribution to Electrodynamics,"^[6] whose publication was suppressed by Rudolf Clausius, Riemann formulated a relativistic wave theory, based on a concept of retarded propagation of potential.

Whoever should suppose that Maxwell's cleverness of physical-geometric insight surpassed Gauss and Riemann in this respect would

surely be unserious. The problem lay not in formulating a geometric picture of wave propagation, but in resolving the underlying epistemological and ontological paradoxes, which had been buried by the promoters of the Newton hoax. These were to erupt again as the crises in physics around the paradox of wave versus particle, the imposition of an acausal, statistical interpretation of atomic phenomena, and its extension into the nuclear and subnuclear domain. The solution to such problems lies outside the realm of mathematical physics *per se*, at least as so narrowly conceived today. A rebirth of the spirit of Nicholas of Cusa, Johannes Kepler, and Gottfried Leibniz, the founders of all modern science, accompanied by a conscious, joyful, and determined overturning of the Sarpi-Newton hoax will accomplish that task.

The treatise, which now appears for the first time in English, was first published in Leipzig in 1846 on the 200th anniversary celebration of the birth of Gottfried Leibniz. The translation is the result of an 1996-97 collaboration of the late Susan P. Johnson and Laurence Hecht. Prof. Andre Koch Torres de Assis of the State University of Campinas in Brazil recently completed the work of equation editing and reviewing the entire manuscript.

[1] Wilhelm Weber, *Determinations of Electrodynamical Measure, Concerning a Universal Law of Electrical Action*, issued at the founding of the Royal Scientific Society of Saxony on the day of the 200th anniversary celebration of Leibniz's birthday, published by the Prince Jablonowski Society, Leipzig 1846. 146 pages in pdf format. Posted March 2007.
www.21stcenturysciencetech.com/Articles%202007/Weber_1846.pdf

[2] In A.M. Ampère, *Electrodynamiques, uniquement déduite de l'expérience* (Paris: A. Hermann, 1883). A partial English translation appears in R.A.R. Tricker, *Early Electrodynamics: The First Law of Circulation* (New York: Pergamon, 1965), pp. 155-200.

[3] Carl Friedrich Gauss, "The Intensity of the Earth's Magnetic Force Reduced to Absolute Measurement," translated from German by Susan Parmacek Johnson, July 1995,
www.21stcenturysciencetech.com/Translations/gaussMagnetic.pdf

[4] Laurence Hecht, "The Atomic Science Textbooks Don't Teach: The Significance of the 1845 Gauss-Weber Correspondence," *21st Century Science & Technology*, Fall 1996,
www.21stcenturysciencetech.com/articles/Atomic_Science.pdf

[5] "Text of the Gauss-Weber Correspondence," translated by Susan Parmacek Johnson, *21st Century Science & Technology*, Fall 1996,
www.21stcenturysciencetech.com/articles/Atomic_Science.pdf, pp. 22-24 of pdf file.

[6] Bernhard Riemann, *Collected Papers*, translated from the 1892 edition by R. Baker, C. Christenson, and H. Orde (Heber City, Utah: Kendrick Press, 2004), pp. 273-278.

@. Ampère et l'histoire de l'électricité

Une nouvelle plateforme est en cours de construction, avec de nouveaux documents et de nouvelles fonctionnalités, et dans laquelle les dysfonctionnements de la plateforme actuelle seront corrigés.

Parcours historique > Des lois pour le courant : Ampère, Ohm et quelques autres...

In Search of a Newtonian Law of Electrodynamics (1820-1826)

🇫🇷 Français

By Christine Blondel and Bertrand Wolff
Translation by Andrew Butrica

Oersted's experiment reveals methodological differences

Oersted's discovery of the magnetic effects of electric currents [See the page *L'expérience de H.-C. Oersted*] stimulated a proliferation of experimental research and fresh discoveries throughout Europe. Given the complexity of the new phenomena, most physicists and chemists made a greater number of purely qualitative observations.

From the outset, only Ampère and Biot - in competition with each other - attached great importance to the quest for a mathematical law that would express the magnetic action of a current and that would be capable of predicting new experimental results. Jean-Baptiste Biot, author of an acclaimed *Treatise on Experimental and Mathematical Physics (Traité de physique expérimentale et mathématique)*, personally had experimented with Coulomb and was an ardent Newtonian. Rejecting the wealth of experimental qualitative results, Biot sought to find a single law that would express the amount of magnetic force exerted by an infinitely long wire on a magnetic pole as a function of its distance to the wire. For the mathematician Ampère, his own search for an "electrodynamic formula", which he launched less than a month after the announcement of Oersted's discovery, fell within the broader framework of his "grand theory". Indeed, his lectures before the Academy of Sciences gave a large place to hypotheses and to the first experimental verifications of this theory according to which all magnetic phenomena could be reduced to interactions between currents [See the page *Ampère lays the basis for electrodynamics...*]

The law of Biot and Savart

Biot imagined that each "slice" of the conductor, labeled F in fig.1, underwent "a momentary magnetization of its molecules". These slices then were equivalent to the tangential magnetized needles ab, a'b', etc.

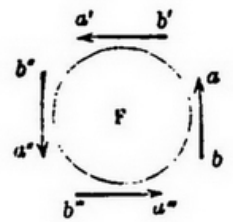


Fig. 1

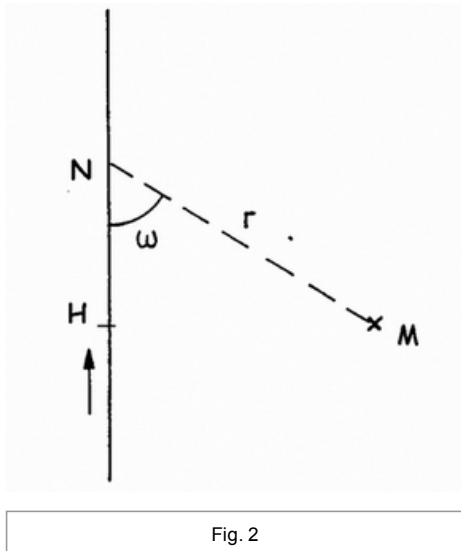


Fig. 2

With Felix Savart, a physician fascinated by acoustics, Biot carried out very precise measurements to determine the force exerted by a conducting wire on the pole of a magnet and to deduce from these measurements a mathematical law for the action of a small slice of the conductor on this pole. Biot stated the law that bears their two names as early as 18 December 1820. According to this law, the force that a thin slice, located at N (fig. 2), of an infinitely long conductor exerts on a "particle of magnetism", placed at point M (fig. 2), is perpendicular to the plane of the figure, and its intensity is proportional to:

$$\sin\omega/r^2$$

where r is the distance between M and the slice located at N, and ω the angle between the straight line MN and the conductor.

What were the series of experimental and theoretical steps that resulted in the formulation of this law?

To study the action of a very long vertical conductor on the pole of a magnet through experimentation, Biot placed a horizontal magnetized needle at various distances from the wire. The influence of terrestrial magnetism on the needle was neutralized by an auxiliary magnet. Following Coulomb's method, he measured the period of the small oscillations of the needle around its point of equilibrium: the force that each pole is subjected to is proportional to the square of this period. This experimental technique was familiar to Biot [On Coulomb's use of this oscillation method, see the page *Les lois fondamentales de l'électricité et du magnétisme*]. The experiment, however, raised new problems. Specifically, the electric current decreased quickly

because of the rapid polarization of the batteries in use at the time.

On 30 October, Biot announced his experimental results: the force exerted by an infinite conductor on the pole of a magnet is inversely proportional to the distance MH of the pole to the wire. As Laplace remarked to Biot shortly thereafter, one could deduce that the elementary force exerted by an infinitesimal wire slice located at a distance r from the pole was proportional to $1/r^2$.

The force exerted by the slice located at N also depends on the angle ω in accordance with a function yet to be determined. To ascertain this function, Biot undertook a second series of experiments. He measured the force exerted on the pole of a magnet M (fig. 3) by an infinitely long conductor forming a variable angle at point A. He concluded from his data that this force was proportional to the angle θ (fig.3).

On 18 December, Biot announced this result. Consequently, he asserted, the elementary force was proportional to $\sin\omega/r^2$. But we can see that there is a problem: the integration of this elementary force $\sin\omega/r^2$ along the length of the bent wire yields a total force proportional to $\tan(\theta/2)$ and not simply proportional to θ . It was only in 1823, after Ampère had highlighted this contradiction, and in remaking his measurements with more care, that Biot found that the total force actually was proportional to $\tan(\theta/2)$ and not to θ . So clearly then Biot derived the factor $\sin\omega$ not from experimentation but from intuition. If one considers that the force exerted by slice N is greatest for $\omega = 90^\circ$, the opposite for $\omega = -90^\circ$ (the direction of the current reversed), and null for $\omega = 0$, then the simplest trigonometric function that satisfies these conditions is $\sin\omega$.

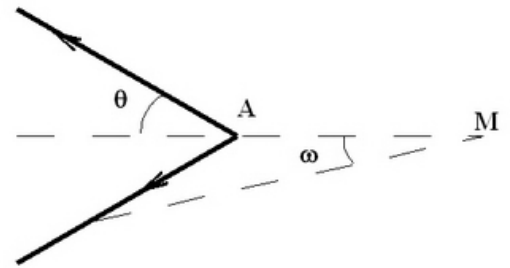


Fig. 3

In modern notation, the "Biot-Savart Law" law is written: $d\mathbf{B} = \mu_0 4\pi I d\mathbf{s} \wedge \mathbf{r} / r^3$ where the bold characters designate vectors, or in norm

$$dB = \mu_0 4\pi I ds \sin\omega / r^2$$

If the factor $\sin\omega/r^2$ originated from Biot (and Laplace), the factor $I ds$ that appears in this modern form, as we shall see, marked the triumph of Ampère's current element over Biot's magnetized slice!

The elementary force being proportional to $1/r^2$ followed closely in the tradition of Newton and Coulomb. However, it did not obey the Newtonian principle of action and reaction, because it was not directed along the line MN (fig. 2). It was, to use the terminology of those times, a "transversal" force perpendicular to the plane defined by MN and the wire.

Moreover, for Biot, the action of the slice was a composite action. For him the problem of the action of a conducting wire on a magnet was far from being resolved:

"It remains to be found how each infinitely small molecule of the connecting wire contributes to the total action of the slice to which it belongs."

In this way the action of a current on a magnet could be reduced to simple magnetic interactions. Biot maintained that it was possible to conceive of an assemblage of miniscule magnetized needles along the circumference of the wire and from which one could deduce his experimental law. But he acknowledged "great difficulty" in achieving that goal.

Ampère's "program"

While Biot sought to reduce the action of a conducting wire on a magnet to magnetic interactions, Ampère in contrast reduced them to the interactions between currents.

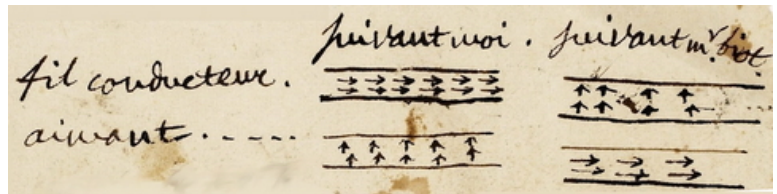


Fig. 4. Ampère employed arrows to represent his elementary currents ("suivant moi" i.e. "according to me") as well as the elementary magnets of Biot ("according to M. Biot").

The portion of the current that he considered was not the infinitely thin slice imagined by Biot, but rather an element of infinitesimal length ds . One could derive the force between two finite currents, at least theoretically, by two successive integrations of the elemental force between two current elements ds and ds' . For the action between a magnet and a current a triple integration would be necessary, each slice of the magnet containing in effect, according to Ampère, an infinity of coaxial circular currents.

But, while one can go from the elemental force to the total force through integration, the reverse is not possible. Biot collided with the same problem and, as we saw, determined its angular factor by intuition, not experiment. How then can one determine the elemental force between two current elements?

Ampère adopted a very original strategy. He proposed to start from the most general interactive force possible and to determine its expression by qualitative experiments on finite circuits. In good Newtonian style, Ampère assumed that this elementary force should obey the principle of action and reaction, and therefore it would be directed along the straight line that joined the two current elements.

The view today is that the forces between finite circuits do obey the principle of action and reaction, but it does not require that forces between infinitesimal elements obey this principle. Ampère however attributed a concrete nature to these elementary forces.

The circuitous path of Ampère's thinking as it meandered between experiments, calculations, and theoretical arguments is too complex to be presented here in detail. We therefore will stay within the broad outlines at the risk of giving an incomplete picture of the breadth of his work that was interrupted and restarted several times over many years. To appreciate the full measure of Ampère's intellectual audacity, his experimental ingenuity, and the sophistication of his lengthy mathematical reasoning, please consult the [Publications d'Ampère](http://www.ampere.cnrs.fr/publications/ampere/).

"A hypothesis . . . the simplest that one could adopt"

Shown here (fig. 5) are two current elements located at A and B. Their lengths are assumed to be infinitely small compared to the distance AB. The intensity of the force between these elements depends not only on the distance $r = AB$, but also on the three angles α , β and γ that define the relative positions of the two elements in three-dimensional space.

Ampere's first hypothesis was that the elementary force decreased "inversely with the square of this distance in accordance with what one observes for all types of action more or less analogous to this one." Like Biot, it remained for him to determine how it varied with the angles.

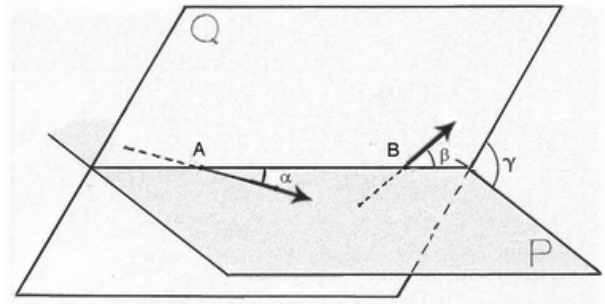


Fig. 5 . The current element at point A is in plane P. The current element at B is in plane Q.

Fig. 6. A straight wire and a "sinuous" wire. If they carry currents in opposite directions, they exert counteracting actions at a substantial distance.



Several experiments suggested the idea that we call today the vector addition of current elements, that is to say, the possibility of replacing a current element with its projections along three axes. One of the experiments substantiating this property was the one showing that a "sinuous" wire and a straight wire exerted equal forces on a moving circuit or a compass. [See the video [L'expérience du courant sinueux](#) .

All that was then needed was to analyze each current element individually along the three orthogonal axes and to consider the forces acting among these components in pairs.

Experiments showed Ampere that two parallel wires attracted each other when they were carrying currents flowing in the same direction, and they repelled each other if the currents ran in opposite directions. He maintained that it was the same for two current elements that were infinitely small and parallel. Furthermore, Ampere was led to suppose that the force between two elements was zero, if one of them were situated in a plane perpendicular to the other element in its middle. He then arrived at an expression for the elementary force being proportional to:

$$g h (\sin \alpha \sin \beta \cos \gamma + k \cos \alpha \cos \beta) / r^2 \quad (1)$$

where g and h depended on "the electricity passing in equal time periods". Here is a first definition of the notion of the intensity of a current.

The first term corresponded to the force between the two parallel components and the second to the force between the two collinear components. In the autumn of 1820, Ampere assumed, with some hesitation, that the force between two collinear elements was nil, that is, that $k = 0$.

"It is on these general considerations that I constructed an expression for the attraction of two infinitely small currents, which in truth was a hypothesis, but the simplest that one could adopt, and consequently the one that should be tested first."

he wrote in September 1820 in a manuscript proposing a preliminary formula. The next step would be to deduce mathematically the action between finite currents, and then to compare the results of these calculations with measurements. Ampere described complex apparatus such as the one shown in fig. 7. Did he use them? We find no numerical results in his rough drafts.

His ingenuity in conceiving such new devices, combined with an almost total lack of measurements, is a rather general characteristic of Ampere's approach in physics. In this first phase of his research, in the absence of exact measurements, qualitative experiments strongly influenced his theoretical thinking.

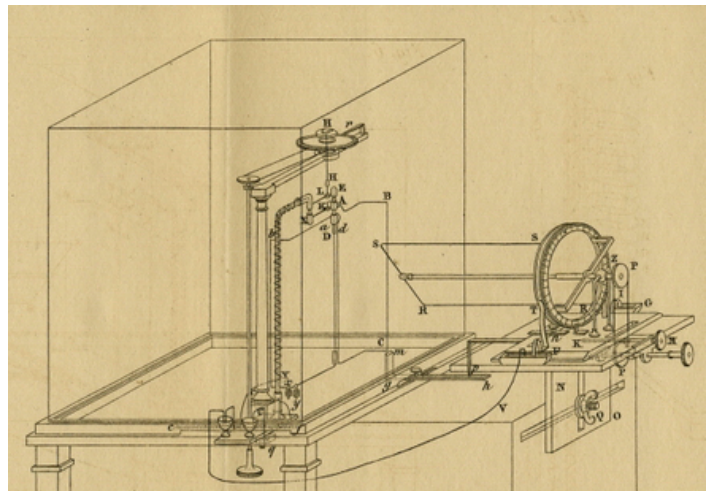


Fig. 7. Apparatus imagined for measuring the force between the moving (vertical) conductor BC and the fixed conductor RS capable of being positioned at various angles.

On 4 December, he had his first notable success: Ampere announced that he came upon - with the aid of this preliminary formula - the experimental results of Biot that gave a force of $1/r$ for an infinite wire acting on a magnetic pole (fig. 2). To that end, he conceived any bar magnet as a set of currents in planes perpendicular to the axis of the magnet.

Ampere's hypothesis thus led to results consistent with experiment. Additionally, it had the advantage of avoiding the "gratuitous assumption" of the

magnetization of the wire. On the other hand, in the eyes of Biot and his partisans, it was the currents within the magnets that were the gratuitous assumption! [See the page [Des théories mathématiquement équivalentes, physiquement différentes](#)].

This phase of research, interrupted by illness, ended in January 1821.

A cold reception and surprising repercussions

Ampere's theory was far from receiving unanimous support. The relative confusion of memoirs written in haste, the difficulty of other physicists trying to repeat his radically new experiments, the reluctance toward what seemed to some people an abuse of the infinitesimally small, all of these contributed to misunderstanding, even distrust. More fundamentally, the hypothesis of the existence of electric currents within magnets aroused skepticism. In England, Faraday praised Ampere's experiments and the ingenuity of his theory, but he doubted the reality of currents not proven directly by experiment

It was a discovery by Faraday that relaunched Ampere's research in the autumn of 1821. Faraday announced that he had achieved the continuous rotation of a magnet under the action of a conductor and vice versa. These continuous rotations astonished Ampere a great deal. [See the page [Faraday, Ampère et les rotations continues](#)].

Replacing the magnet with a solenoid, he realized continuous rotations solely with circuits, which further supported his theory. On the other hand, it was impossible for him to obtain these rotations with only magnets. For Ampere, that fact dealt a fatal blow to Biot's theory: one could not reduce electromagnetism to interactions between magnets.

Towards a new method: the case of equilibrium

Little by little Ampere abandoned all plans to realize absolute measurements of electrodynamic forces. Starting in 1822 a new method was underway: the use of "cases of equilibrium". As a result, Ampere forged what has since come to be called the "zero method". The idea was to make two circuits traversed by the same current act simultaneously on a movable conductor in such a way that the forces created by the two circuits on the mobile conductor counterbalanced each other exactly. To eliminate the parasitic action of terrestrial magnetism on this mobile circuit, Ampere imagined "astatic" circuits such as those represented in fig. 8.

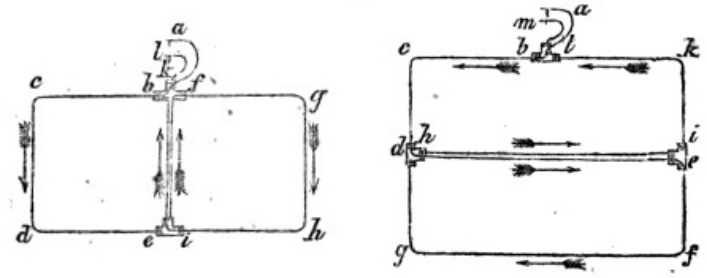


Fig. 8. Two examples of circuits insensitive to terrestrial magnetism To make a mobile circuit insensitive to terrestrial magnetism, Ampere added to it a second circuit that was contiguous on one side. He then called the ensemble "astatic". [See the video [Un circuit mobile d'Ampère](#)].

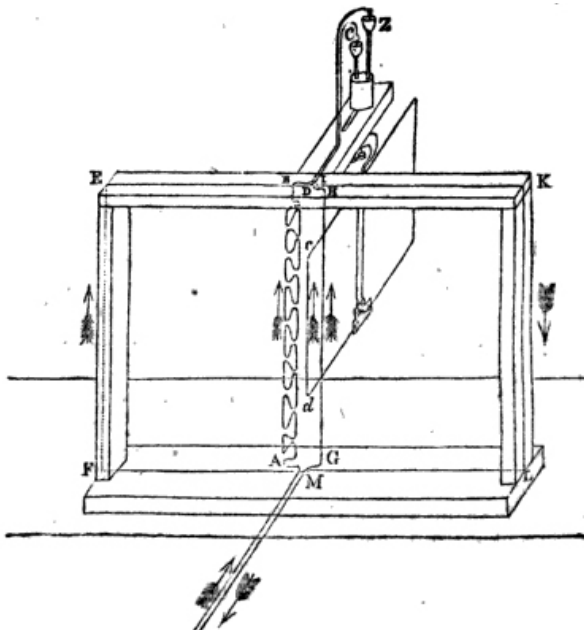


Fig. 9. The actions exerted simultaneously by a curving current and a rectilinear current on the side cd of an astatic mobile circuit compensate for each other (the frame EFKL serves to support the connecting wires between the mobile circuit and the battery).

Ampere was led to this method by two experiments that already constituted "cases of equilibrium": first two parallel, equal, adjacent, and opposite currents have no action, second a straight current and a "sinuous" current (fig. 6 and 9) are equivalent.

The discovery of a third case of equilibrium from the experiments with continuous rotations led Ampere to two important conclusions:

- The force exerted by any given closed circuit on a current element is always perpendicular to this element
- The coefficient k for the elementary force is not zero but equal to $-1/2$.

A mutual non-zero action between two collinear elements?

We saw above that a non-zero value for k implied the existence of a force between collinear elements. Ampere thought to confirm this conclusion with an

experiment conducted in 1822 in Geneva. The two branches of a metal wire in the form of a hairpin floated on a mercury surface in two independent compartments of a circular vessel (fig. 10). The end of each branch was in contact with a metal wire connected to a battery. When the current was started, the branches moved away from the contacts regardless of the direction of the current. [See the video [L'expérience du conducteur flottant](#) 65]. For Ampere, this "indicated a repulsion for each wire between the current established in the mercury and its extension in the wire itself," and he concluded: this "is a great proof in favor of [my] formulas."

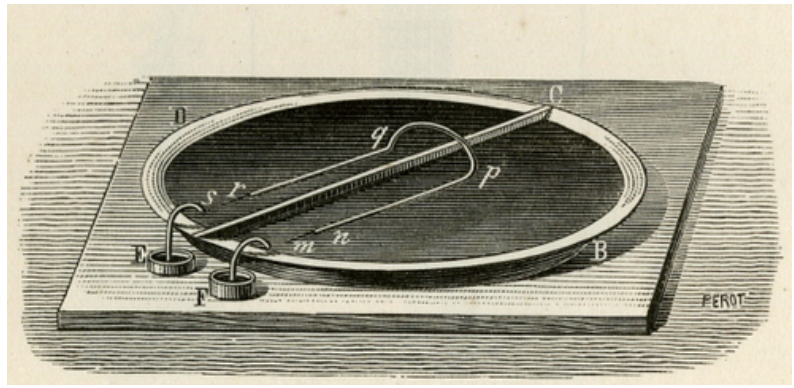


Fig. 10. The experiment with the floating conductor intended to show the repulsion of collinear currents.

This experiment, one of Ampere's rare experiments that has appeared in physics textbooks into the twentieth century, is interpreted today by the "rule of maximum flux": a bendable circuit takes a form giving it the maximum surface area in such a way as to be traversed by a maximum of magnetic flux. The flux in this case is the flux created by the magnetic field of the circuit itself.

A "définitive" formulation

Ampere then announced his definitive formula. He specified the factors g and h in formula (1) as the intensities of the currents and defined the way to measure these intensities by the force that a current exerts on a parallel current taken as a reference. By replacing k with the value $-1/2$, the mutual action between two infinitely small current elements with lengths ds and ds' became:

$$i' ds ds' (\sin \alpha \sin \beta \cos \gamma - \frac{1}{2} \cos \alpha \cos \beta) / r^2 \quad (2)$$

The mathematical consequences of the elementary law

As such Ampere did not consider his task complete. He wanted to show that his formula predicted all possible cases of interactions between currents and magnets. In this effort Ampere benefited from the valuable collaboration of two young men, Félix Savary and Jean-Firmin Demonferrand. The *Manuel d'électricité dynamique* of the latter, published in 1823, had a wider circulation than Ampere's own collected electrodynamic observations *Recueil d'observations électro-dynamiques* published somewhat earlier. Savary deduced the law of Biot and Savart from Ampere's elementary formula and in the process pointed out the inconsistencies of Biot in his determination of that law. Coulomb's law for magnetic poles equally became a mathematical consequence of Ampere's formula. In February 1823, Ampere declared that, thanks to Savary and Demonferrand, "all the facts not yet explained completely [...] are necessary consequences of his formula".

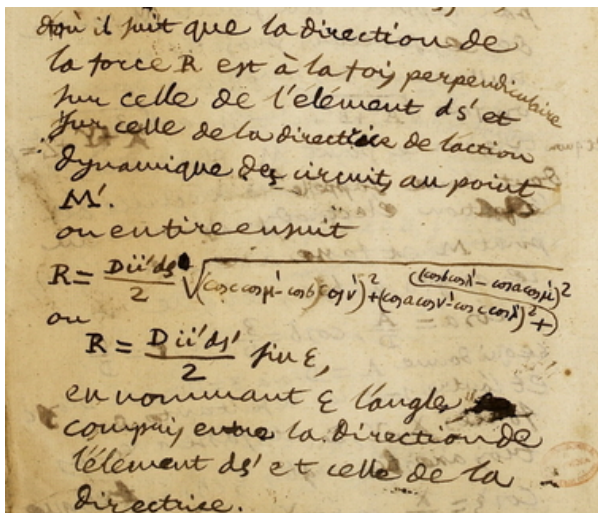


Fig. 11. Ampère manuscript showing the "directrice" and the expression $\frac{1}{2} D i' ds' \sin \epsilon$

These successes motivated Ampere to carry out new research on the action of whatsoever kind of closed circuit on a current element. In the course of his calculations, Ampere introduced an important calculating aid: a line that he called the "directrice". At each point in space this line has a specific direction that depends only on the closed circuit (and not the orientation of the current element). Ampere showed that the force experienced by current element ds' located at a given point is perpendicular to the directrice at that same point. The force equally being perpendicular to the current element, it is therefore perpendicular to the plane defined by the directrice and the element.

Finally, if the angle between the directrice and current element ds' was ϵ , Ampere showed that one could write the intensity of the force in the form:

$$\frac{1}{2} D i' ds' \sin \epsilon \quad (3)$$

where D was a quantity that depended only on the geometry of the closed circuit and the point where the current element was found.

We recognize here the expression of the law known in France as Laplace's law:

$$dF = i' ds' \cdot B \sin \epsilon$$

or in vector form: $d\mathbf{F} = i' d\mathbf{s}' \wedge \mathbf{B}$ (4) where the intensity B of the "magnetic induction vector" is, by nearly a factor, the product Di and its direction that of the *directrice*.

But the similarity of mathematical formulas should not make us forget that the present day formulation in terms of magnetic induction implicitly supposes the notion of a field, that is to say, the idea that the space around a circuit undergoes a modification characterized at each point by a physical quantity. Furthermore, the mathematical definition of a vector did not come along until after Ampere.

Beginning in the winter of 1823-1824, Ampere was overwhelmed by personal problems and his teaching load. It was only in August 1825 that he returned to electrodynamics.

Two new cases of equilibrium

Striving to establish his formula in a more general way, Ampère assumed the elementary force to be proportional to $1/r^n$ with n an integer, and no longer a priori $1/r^2$. He also was dissatisfied with the third case of equilibrium that allowed him to determine the value of the constant $k = -1/2$. So, he started from the most general expression of the elementary force deduced from the first two cases of equilibrium:

$$i \, ds \, i' \, ds' (\sin \alpha \sin \beta \cos \gamma + k \cos \alpha \cos \beta) / r^n.$$

A new experiment, which became his third case of equilibrium, intended to show that a closed circuit placed in the vicinity of a small portion of a conductor can make it move only in a direction perpendicular to the conductor (fig. 12). But the experiment was, by Ampère's own admission, "hardly prone to accuracy" mainly because of friction. The expected result of this experiment provided, at the cost of long calculations, a relationship between n and k : $2k + 1 = n$.

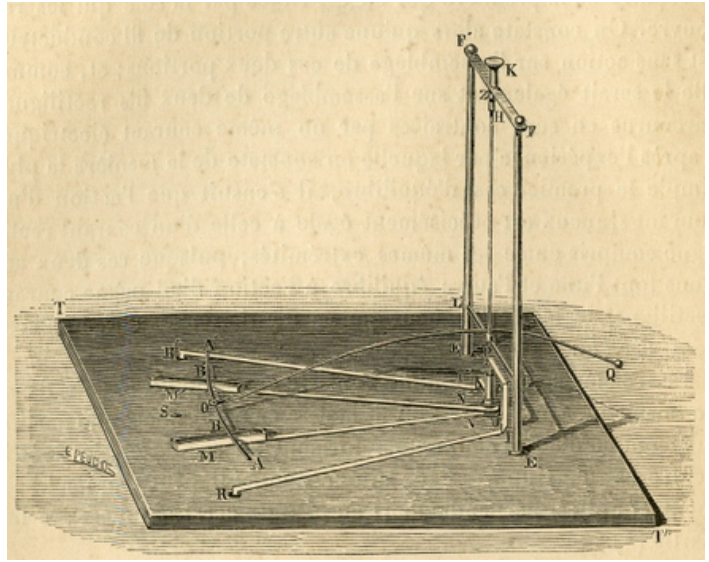


Fig. 12. An arc (AA), capable of being moved over troughs of mercury that connect it to a battery, can move only by turning around its center. When it is subjected to the action of an external circuit, it remains motionless. This third case of equilibrium proved to Ampère that the force has no component tangential to the arc and is therefore perpendicular to it.

A fourth and last case of equilibrium consisted of making two fixed circular circuits, one p times smaller, the other p times larger (fig. 13). The two fixed circles were placed on either side of the movable circle, the distances between the centers of the circles being in the same relationship p as their radii.

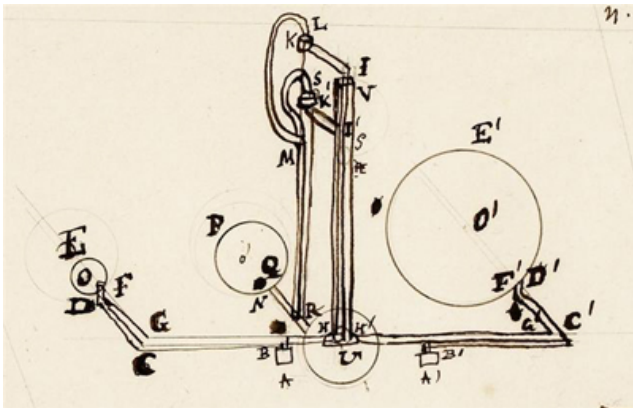


Fig. 13. The fourth equilibrium case

In this manuscript drawing, Ampère did not respect the rules of perspective for the three circles which are in the same horizontal plane. The centers of the three circles are aligned. The movable circle PQ is part of an astatic circuit along with a second circle traversed by a current flowing in the opposite direction. This arrangement compensates for the influence of terrestrial magnetism.

A rather simple argument shows that, if the movable circle remains in equilibrium under the opposing actions of the two fixed circles, the exponent n takes the value 2. Ampère thus again found that the value $k = -1/2$.

The electrodynamics formula - obtained essentially by trial and error - was thus "demonstrated"

Ampère now had at his disposal all the elements that he deemed necessary for the definitive account of his theory. The synthesis of his many publications scattered in various journals became his *Théorie des phénomènes électrodynamiques, uniquement déduite de l'expérience* [Theory of Electrodynamical Phenomena Deduced Solely from Experiment], published in 1826.

The *Théorie [mathématique] des phénomènes électrodynamiques...*

"Ampère's theory of the mutual action of electric currents is founded on four experimental facts and one assumption", wrote Maxwell in the final chapter of his *Treatise on Electricity and Magnetism* (1873), that he dedicated to Ampère. The four experimental facts were the four cases of equilibrium. The hypothesis was that of the instantaneous action at a distance between current elements obeying the principle of action and reaction and, therefore, directed along the line that joined these two elements.

The first two cases of equilibrium - the reversal of the direction of the force with the reversal of the direction of the current and the experiment with the sinuous current - legitimated, as we have seen, the analysis of current elements along three axes from which one can deduce that the mutual action necessarily has the expression:

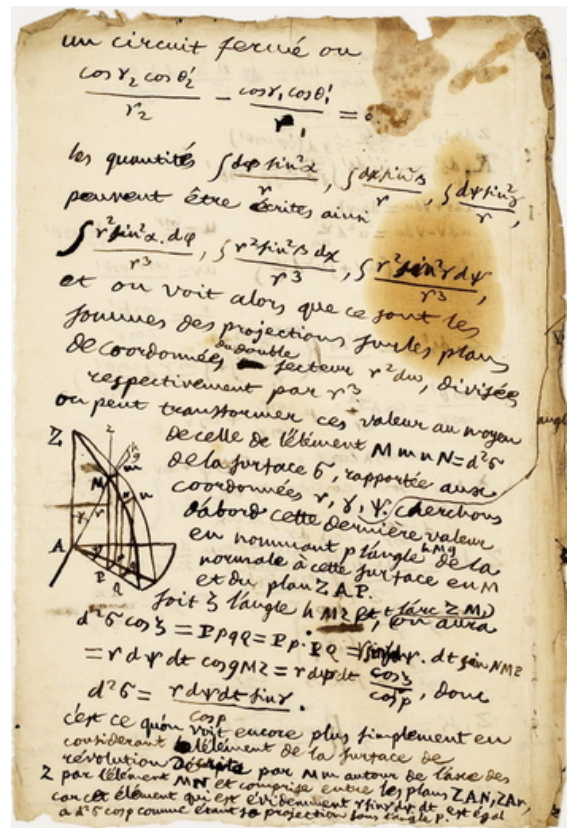
$$i \, ds \, i' \, ds' (\sin \alpha \sin \beta \cos \gamma + k \cos \alpha \cos \beta) / r^n$$

The two last cases of equilibrium determined that $n = 2$ and $k = -1/2$.

The derivation of this elementary force occupied barely the first quarter of the *Théorie [mathématique] des phénomènes électrodynamiques*. The rest was devoted to very long calculations extending this work into specific problems. These deal first with obtaining the laws of interactions among all types of circuits by integrating the formula. One of the calculations concerned the mutual action of two parallel rectilinear conductors carrying currents of intensities I and I' . Ampere showed that the force exerted by one of the conductors, considered as being infinitely long, on a portion of the other conductor whose length is L , is proportional to $I I' L / a$, where a is the distance between the two wires. It is from this force between two parallel currents that we define the unit of intensity in the present international system of units and which in 1881 received the name Ampere. [See the page [Le système international d'unités](#)]

By means of even longer calculations, Ampere established the equivalence between a bar magnet and a solenoid. He also showed that any given closed circuit was equivalent to a set of two surfaces infinitesimally close to the circuit and over which were spread the two opposite magnetic fluids (a "magnetic leaf"). From that moment forward electrodynamics encompassed all magnetic phenomena.

Fig. 14. Extract from Ampere's calculations concerning the interactions between circuits



Ampere's formula: a formula with an ambiguous appraisal...

The title of Ampere's treatise asserts that the theory was "derived solely from experiments". The treatise's first page presents a bubbly tribute to Newton:

"Observe first the facts, vary the circumstances as much as possible, carry out precise measurement in order to deduce general laws founded solely on experimentation, and deduce from these laws - independently of all hypotheses about the nature of the forces that produce the phenomena - the mathematical value of these forces, that is to say, the formula that represents them, such is the path taken by Newton. It has been adopted generally in France by savants to whom physics owes the tremendous progress that it has achieved in recent times, and it was what has served me as a guide in all my research on electrodynamic phenomena."

As we have seen, this was not so simple.

What about the four experiments intended as the basis of the theory? Experimental difficulties, Ampere recognized, made the results of his third experiment very doubtful. Regarding the fourth experiment, he wrote:

"I believe I must admit, in finishing this memoir, that I have not had the time to build the instruments [...] The experiments for which they were intended have not been carried out yet; but, as the purpose of these experiments was only to verify a series of results obtained otherwise, moreover as it would be useful to perform them as a counterproof to those that furnished these results, I have not thought it necessary to delete their description."

This admission may be surprising. It illuminates the state of experimentation in this final work in which Ampere aimed to present the ideal development of his formula as it could be derived from a minimal number of experiments. The mathematical consequences for Ampere had the same status as Kepler's empirical laws for Newton's determination of the universal law of gravitation. The absolute confidence that he expressed regarding the result of his fourth experiment - which he quite probably never carried out - rests on "results obtained otherwise," that is to say, by a subtle back and forth between simpler experiments, intuition, and sophisticated computations.

On the other hand, as Maxwell indicated a half-century later, an infinity of differential formulas can yield, by integration, the same expression for the force between two finite circuits. However, if one accepts Newton's principle of action and reaction as applying to the infinitely small current elements, only one elementary formula is possible: that of Ampere, and for Maxwell that, therefore, is the best. We understand why Maxwell called Ampere the "Newton of electricity" (an ambiguous compliment, as Maxwell's own theory broke radically with Newtonian philosophy). Moreover, if Ampere introduced the *Théorie [mathématique] des phénomènes électrodynamiques* with his profession of Newtonian faith and strongly fought the ideas of Biot as being anti-Newtonian, he showed in other texts his repugnance toward the idea of instantaneous action at a distance and his private conviction of a gradual propagation through the ether, the hypothetical medium supposedly filling space ... [See the page [Des théories mathématiquement équivalentes, physiquement différentes](#)]

A final question: as Ampere's formula was undoubtedly effective, why, after having given rise to so much debate, did it disappear from modern science? [See the page [La force d'Ampère, une formule obsolète ?](#)]. In 1888 the English physicist Oliver Heaviside, a disciple of Maxwell, recognized that this formula had been considered by Maxwell himself as the cardinal formula of electrodynamics. But, he added: "If so, should we not be always using it? Do we ever use it? Did Maxwell, in his treatise? Surely there is some mistake." He suggested transferring Ampere's name to the formula that expresses the force undergone by a section of conductor placed in a magnetic field, "it is fundamental and, as everybody knows, it is in continual use, both by theorists and practitioners." But the attribution of a savant's name to this physics formula succumbed to the accidents of history and, paradoxically, at least in France, this force is known as Laplace's force!

Further reading

AMPERE, André-Marie. *Mémoire [...] sur les effets des courants électriques*, *Annales de chimie et de physique*, 1820, vol. 15, p. 59-75, p. 170-218.

AMPERE, André-Marie. Recueil d'observations électrodynamiques, Paris, 1822.

AMPERE, André-Marie. Théorie des phénomènes électrodynamiques uniquement déduite de l'expérience, Paris, 1826.

[Recherches de Jean-Baptiste BIOT in] Société française de physique (Ed.). *Collection de mémoires relatifs à la physique. t. 2, Mémoires sur l'électrodynamique [publiés par les soins de J. Joubert] 1ère Partie*. Paris : Gauthier-Villars, 1885, p. 80-127.

BLONDEL, Christine. Avec Ampère le courant passe, *Les mathématiques expliquent les lois de la nature. Le cas du champ électromagnétique. Les Cahiers de Science & Vie*, 67, 2002, 20-27.

LOCQUENEUX, Robert. *Ampère, encyclopédiste et métaphysicien*. Les Ulis : EDP sciences, 2008.

HOFMANN, James R. *André-Marie Ampère*. Cambridge : Cambridge University Press, 1996.

BLONDEL, Christine. *Ampère et la création de l'électrodynamique, 1820-1827*. Paris : Bibliothèque nationale, 1982.

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@. Ampère et l'histoire de l'électricité

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Parcours historique > Des lois pour le courant : Ampère, Ohm et quelques autres...

Ampère's Force Law: An Obsolete Formula?

🇫🇷 Français

By Christine Blondel and Bertrand Wolff
Translated by Andrew Butrica

It is not uncommon to find in the science of the past some works that never were deemed as being invalid yet have disappeared from modern science. They might have been overturned by subsequent work judged to be more effective, or were abandoned because they were considered to be of little interest, or were discredited for nonscientific reasons, or simply were forgotten. Their status remained undecided. At any moment, though, scientists can take up such an unclaimed work for different reasons. Such is the case of Ampère's force.

Ampère's electrodynamic theory is based on the existence of a force between two current elements, and the mathematical expression of this force implies a repulsion between two aligned elements. However, this interaction between collinear elements disappeared with the elemental force of Grassmann (1845), a force that forms now an integral part of the modern theory of electromagnetism.

In order to decide between Ampère and Grassmann expressions of the electrodynamic force, one can look for experiments relying on the existence, or the non-existence, of a repulsion between collinear elements of an electric circuit. Nonetheless, a direct verification of Ampère's formula and its application to the particular case of collinear elements is not possible. Indeed, one cannot isolate current elements within an electric circuit. Ampère thought, though, to have an experimental proof for the repulsion between collinear elements. We will discuss various experiments proposed at the end of the twentieth century in the continuation of Ampère's experiment and likely to demonstrate the existence of this force. The interpretation of these experiments is still controversial.

From a theoretical point of view, the compatibility between the Maxwell-Lorentz theory and Ampère's force also is a subject of debate.

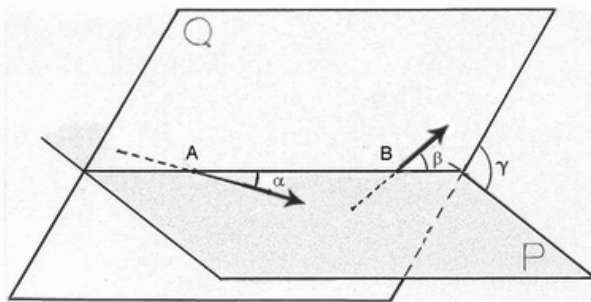
Finally, for some, defending Ampère's force is part of a larger project that consists of developing - following Weber and Neumann - a "Newtonian" alternative to Maxwell's theory, using only interactions at a distance between material elements without recourse to an electromagnetic field. This project may seem foolhardy and based on tenuous foundations, while Maxwell's theory, associated with Einstein's relativity, constitutes a major pillar of modern physics.

We conclude, nonetheless, following Maxwell himself, that it is desirable for the very life of science to leave open a number of paths: "It is a good thing to have two ways of looking at a subject, and to admit that there are two ways of looking at it." (*The Scientific Papers of James Clerk Maxwell*, t. 1, p. 208)

1873: "A formula from which all phenomena may be deduced..."

According to Maxwell himself, "Ampère's theory "is summed up in a formula from which all the phenomena may be deduced, and which must always remain the cardinal formula of electro-dynamics." (*A Treatise on Electricity and Magnetism*, 1873, t. 2, p. 175).

This fundamental formula of Ampère expresses the force exerted by one infinitesimal current element $i ds$ on another infinitesimal current element $i' ds'$, placed at a distance r from each other and whose relative positions are defined by the three angles α , β and γ [See the page [In Search of a Newtonian Law of Electrodynamics](#)].



Ampère's elementary force between $i ds$ and $i' ds'$:
 $i i' ds ds' (\sin \alpha \sin \beta \cos \gamma - \frac{1}{2} \cos \alpha \cos \beta) / r^2$

Fig. 1. The current element ds , located at point A, is situated in the plane P; element ds' located at point B is in the plane Q.

From this formula Ampère could calculate, by a double integration, all the interactions between real circuits. Applying this method to the small circular currents, which he supposed to exist in the interior of magnets, he obtained the laws of interaction between two magnets or between a magnet and a current. Relying on this formula one can, as Maxwell wrote, "deduce all phenomena."

1958: A formula that "no longer serves any purpose"

In 1958, Edmond Bauer, who had collaborated with Paul Langevin on his theory of magnetism, reworking Ampère's fundamental ideas, reissued Ampère's great synthesis, *Mathematical Theory of Electrodynamical Phenomena Uniquely Deduced from Experiment*. In his foreword, which elsewhere is strongly laudatory, Bauer wrote: "the famous formula of Ampère no longer serves any purpose." Indeed, after having prevailed in France until the 1890s, Ampère's theory gradually was abandoned. At the beginning of the twentieth century, physicist Henri Bouasse could assert in his treatise on electricity:

"The formula of Ampère no longer offers any but an historical interest. It's a waste of time to discuss the hypotheses on which Ampère relied to establish it, or the consequences that it specifies for the actions between two elements in specific positions."

If today one still finds an "Ampère formula" in certain physics texts, in most cases it is not Ampère's original formula, but that proposed in 1845 by the German mathematician Hermann Grassmann. This pioneer of vector analysis defined a "geometric product" from which one later would derive the usual vector product. Thanks to the use of this new mathematical concept, his force appeared to offer greater simplicity over that of Ampère. But, unlike the latter, it did not satisfy the principle of action and reaction.

The elementary force of Grassmann (exerted by element $\mathbf{id}\mathbf{s}$ on element $\mathbf{i'ds'}$), in modern symbols:

(The vector quantities are represented by bold characters)

$$\mathbf{i'ds' \wedge id s \wedge r r 3}$$

Intensity of the force: $i' ds ds' \sin \alpha \cos \beta$ (β being the angle between $\mathbf{ds'}$ and plane P).

This force, whose expression does not assign a symmetric role to the two elements $\mathbf{ds}$ and $\mathbf{ds'}$, is always perpendicular to the element $\mathbf{ds'}$.

The 1980s: Ampère's formula, a new scientific challenge?

Since the 1980s, a certain number of physicists - supported by theoretical work as well as by experimental results - have believed that one must bring back from oblivion Ampère's original formula, which now finds itself nearly two centuries after its "invention" the subject of scientific controversy.

Some even claim that several experiments can be explained only by Ampère's formula.

Are we returning to an archaic past, rendered outdated by the electromagnetism of Maxwell-Lorentz? Did Ampère's formula simply fall out of use, lapsed without being challenged, dethroned by a theory that was more fruitful, more aesthetic, and easier to apply, or is it incompatible with modern electromagnetism, which explains a great number of phenomena?

The ambiguity of Maxwell's judgment

While Maxwell considered Ampère's formula to be "fundamental", he nonetheless added:

"Hence no statement about the mutual action of two elements of circuits can be said to rest on purely experimental grounds." (A *Treatise*..., vol. 2, p. 163)

Indeed, as electric currents form closed circuits, it is impossible to isolate physically the action of a current element (we are not considering here open circuits as a radio antenna, seat of high-frequency electrical oscillations). While many experimental tricks allow one to make a small portion of a circuit (C') mobile, this portion is subject to the action of the entire circuit (C), but one cannot isolate the action of a single one of circuit (C) elements.

An infinity of elementary formulas, including those of Ampère and Grassmann, can lead to the same force exerted on element $\mathbf{i'ds'}$ by integration over the totality of the circuit (C).

Why, then, does the same Maxwell describe Ampère's formula as a "fundamental formula of electrodynamics"? Indeed it is the only one that respects the Newtonian principle of action and reaction. In general Grassmann's force is not carried along the straight line that joins two elements. In addition, Grassmann's force $\mathbf{i'ds' \wedge id s \wedge r r 3}$ exerted by the element $\mathbf{id}\mathbf{s}$ on element $\mathbf{i'ds'}$ does not have the same intensity as that exerted by $\mathbf{i'ds'}$ on $\mathbf{id}\mathbf{s}$, obtained by reversing the roles of the two elements.

As the physicist R.A.R. Tricker has emphasized, today we consider Newton's principle as applying only to finite forces, having a physical reality, therefore to the forces between circuits:

"The reader may well take the view that questions which, even in principle, cannot be put to the test of experience [such as the correct elemental formula], do not belong to science, but in spite of this Ampère has been subjected to considerable criticism. Curiously enough, the one criticism to which he would be vulnerable, [was] namely that he, too, along with most of his critics, thought that he was arriving at the law of force which current elements *actually* exerted upon each other..." (R.A.R. Tricker, *Early Electrodynamics*, 1965, p. 99)

Ampère's formula dethroned by Maxwell's equations and "Laplace's force"

By integrating Grassmann's force $\mathbf{i'ds' \wedge id s \wedge r r 3}$ over the circuit (C), one obtains the force $\mathbf{dF}$ exerted by this circuit (C) on the element $\mathbf{i'ds'}$ of circuit (C'):

$$\mathbf{dF} = \mathbf{i'ds' \wedge (\text{summation over C})}$$

The result of the summation over (C) subsequently was identified as being the magnetic field $\mathbf{B}$ created by circuit (C). Grassman's force thus takes the simple vector form $\mathbf{dF} = \mathbf{i'ds' \wedge B}$. This force is perpendicular to $\mathbf{ds'}$ and to $\mathbf{B}$, and its intensity is $i'ds'B \sin \epsilon$, where ϵ is the angle between $\mathbf{ds'}$ and $\mathbf{B}$. In France, at least, this law is known as "Laplace force".

$$\text{Laplace force: } \mathbf{dF} = \mathbf{i'ds' \wedge B}$$

Ampère had established an equivalent law [See the page [In Search of...](#)]. Indeed, he showed that the force exerted by a closed circuit on element $\mathbf{ds'}$ was perpendicular to this element and to a straight line that he called the *directrice*. He expressed the intensity of this force as:

$$\frac{1}{2} D i' ds' \sin \epsilon.$$

One can recognize in the factor $\frac{1}{2} D i'$, associated with the *directrice*, the characteristics of the magnetic field $\mathbf{B}$. But, Ampère saw in this law only a mathematical consequence of an action at a distance between current elements.

The triumph of Maxwell's theory, based on the continuous propagation of electromagnetic actions, explains the abandonment of Ampère's formula in favor of Grassmann's which fits perfectly into the Maxwellian framework, because it is easy, as we have seen, to link it to the field. Maxwell's homage to the historical Ampère's formula is thus somewhat paradoxical.

Repulsive forces between collinear elements?

A question remains open. Could one, contrary to what Maxwell asserts, decide between the elementary formulas of Ampère and Grassmann by experiment? And if experiment decided in favor of Ampère's force, would that challenge the edifice erected by Maxwell, itself inextricably linked to the theory of relativity?

Ampère's formula implies, in contrast to that of Grassmann, the existence of a repulsive force between two collinear current elements. Indeed, if the two elements are collinear, the angles α and β (Fig. 1) are zero and the force between ds and ds' becomes:

$$-\frac{1}{2} i i' ds ds' / r^2.$$

The force being negative, it is a repulsion. In contrast, Grassmann's formula, $dF = i i' ds ds' \sin\alpha \cos\theta$, implies that the force between collinear ds and ds' is zero.

According to Ampère, in a metal wire carrying a current, there should be a repulsive force between two consecutive elements. So, could we decide between the two formulas by studying the action exerted between two parts of the same circuit?

Ampère's "hairpin experiment" revisited in the 1980s

In 1822, Ampère thought he held a proof in favor of his formula with his experiment of the floating conductor, sometimes called the "hairpin experiment". [See the video [L'expérience du conducteur flottant](#) on the page [In Search of...](#)].

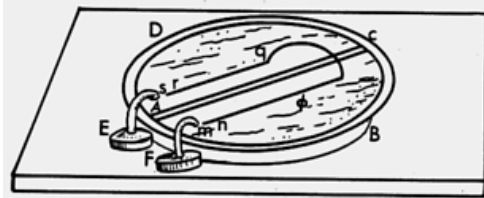


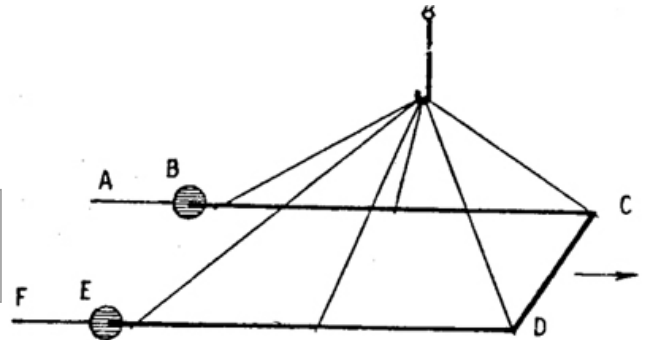
Fig. 2. A copper wire nqr , in the shape of a hairpin, insulated except for the bare ends n and r , floats on the surface of the mercury contained in two sections of a circular container. When a strong current flows through the circuit, the hairpin wire moves away from the fixed contacts s and m regardless of the direction of the current.

During the 1980s, several researchers revisited this experiment.

- Peter Graneau at MIT observed in 1981, with currents of several hundred amperes, strong turbulence in the mercury when the movement of the hairpin was blocked. This turbulence seemed to manifest the repulsion undergone by the portion of mercury carrying the current

- Panos T. Pappas in 1983 replaced Ampère's hairpin with a wire formed into a rectangle lacking one of its shorter sides and suspended in a way to constitute a pendulum (Fig. 3). The author determined the amount of motion communicated to the pendulum, and he attributed this motion to Ampère's repulsive force. This experiment was executed with greater precision by Peter and Neal Graneau (1986) using the discharge of a series of capacitors.

Fig. 3. The principle of Pappas' impulse pendulum. The ends of the movable conductor are in electrical contact with the fixed terminals of a battery via the small cups of mercury B and E. When the current is turned on, the pendulum undergoes a repulsion and electrical contact is broken.



- Still in line with Ampère's experiment, other physicists have sought to "weigh" the possible repulsive force. Thus Peter Graneau in 1986, then Rémi Saumont in 1992, suspended the same type of mobile conductor in the form of an incomplete rectangle vertically under the pan of a precision balance. The vertical repulsive force that it underwent from the fixed part of the circuit then could be measured.

Contradictory interpretations

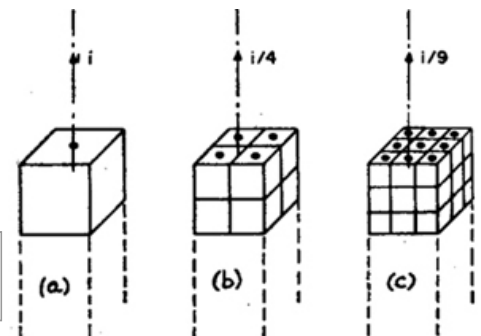
In fact the different variations of Ampère's experiment are interpreted in the context of modern physics by using the Laplace force, and therefore the elemental force of Grassmann. Indeed the transverse part of incomplete rectangles is subject to a Laplacian force under the action of the magnetic field created by the circuit. This force is perpendicular to the transverse portion, and therefore tends to separate the movable part from the rest of the circuit.

Only the calculation of the intensity of the force experienced by the movable part would be likely to decide between the two basic laws. But, can one calculate, by integrating Ampère's formula, the repulsive force between two parts of the same circuit? If one likens the conductor to a line without thickness, divisible into "infinitely short" current elements, integration leads to an infinite force between two adjacent collinear elements.

In contrast, several authors have proposed calculating methods that better take into account the actual structure of conductors: a current element is not infinitely short and the wire diameter is not zero.

- For Graneau, the size of the current element cannot be smaller than that of the unit cell of the metallic lattice, of the order of a nanometer. Computers performed numerical integrations by summation over a large number of small elements but the size of these elements remains much larger than a nanometer. By extrapolating from the results obtained, it is hoped to obtain an order of magnitude of the force [Graneau, 1986].

Fig. 4. The principle of calculation by summation over finite elements [Graneau, 1986]. When one divides a conductor into smaller and smaller elements, the force calculated by this method of approximation increases, but less and less rapidly as one approaches atomic magnitudes.



- Other writers, taking into account a volumetric distribution of the current in a conductor with a non-zero diameter, avoid choosing numerical methods and perform integrations. They therefore must deal with sextuple integrals [Marcelo Bueno and A. K. T. Assis, 1996].

- Finally, calculations can be performed more easily within the framework of classical electromagnetism using the expression for the inductance of the circuit, a notion that came along well after Ampère [R.A.R. Tricker, 1965, or Bueno and Assis, 1998].

Regardless of the calculating method chosen, the force exerted by a circuit on one of its elements has a value low enough so that the mechanical stresses remain imperceptible in solid conductors, at least as long as the current has not an unusually high intensity. But it can explain the observed effects in circuits with liquid or movable part, as in the previous experiments.

Some authors conclude with the triumph of Ampère's formula. According to them, integrations based on Grassmann's formula lead to clearly weaker forces. However, in 1996, Assis and Bueno corrected an error in the reasoning underlying these calculations and achieved, using Grassmann's formula, the same results as with Ampère's formula. In 1998, they also showed that the inductance method constituted an indirect proof of the equivalence between the formulas of Ampère and Grassmann.

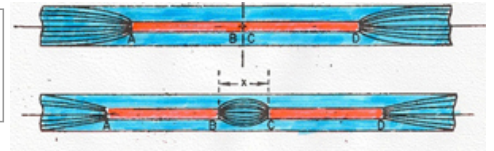
Consequently it does not seem possible to decide between the formulas of Ampère and Grassmann by experiments of Ampère's type.

Other experiments enter the controversy

The previous experiments considered the overall force exerted by a circuit on one of its parts. While the formulas of Grassmann and Ampère give the same result for this overall force, they may not be equivalent for the distribution of force along the circuit. In order to test this hypotheses, some tried to highlight *local* effects of longitudinal forces, effects for which only Ampère's force could account.

- Inspired by an experiment performed by Neumann for his students during the 1880s, Graneau placed two short copper rods end to end in a rectilinear narrow channel filled with mercury. When this channel carried a current of 450 amps, the two rods repelled each other.

Fig. 5. In the middle of a long channel of mercury, two copper rods AB and CD are placed end to end. When current flows, the rods repel each other. (The rods are covered with insulation, and the conductivity of copper is much greater than that of mercury, which explains the pattern in black of the lines of current). Graneau, 1986.



- In the early 1960s, Jan Nasilowski already had noticed that a very strong flow of current caused the explosion of conducting wires into a series of fragments (Fig. 6). Graneau repeated the experiment in the 1980s with currents of more than 5,000 amps but of short enough duration to keep the temperature well below the metal's melting point. Examination of the microscopic structure of the fracture regions seemed to confirm a mechanical cause. The fractures, therefore, could be due to Ampère's force.

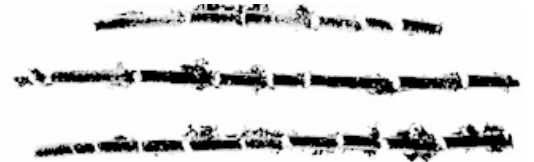
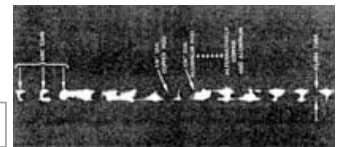


Fig. 6. Fragments resulting from the explosion of conductors [Jan Nasilowski].

- In another experiment [Linda J. Ruscak and R. N. Bruce, 1987] a copper rod one meter long was cut into segments of one centimeter and stacked in a glass tube. Springs held them firmly in contact with each other. Current pulses ranging from 3 to 30 kiloamps caused them to separate, while electric arcs leaped in the gaps.

Fig. 7. Separation and formation of arcs between copper segments in the experiment of Ruscak and Bruce.



- One will add an experiment carried out after the observation of a paradoxical effect during experiments on the "electromagnetic railgun" for the U.S. Strategic Defense Initiative. The left part of Figure 8 shows the very simple principle of the railgun or "cannon". When a very intense current flows in the circuit consisting of two long horizontal rails and a movable bar placed on these rails, the bar starts to move. The imparting of motion to the projectile is explained very classically by the Laplace force experienced by the movable bar in the circuit's own magnetic field. In 1984, with a peak intensity of more than 2 million amps, it was possible to drive an object weighing 300g at a speed of 15,000 km/h.

During this experiment, it was observed that the rails had undergone unexpected mechanical deformations. Graneau then modified the experiment (Fig. 8, on the right) by blocking the crossbar. Pulses of 100 kiloamps were enough to cause deformations in the thinnest parts of the rails which he attributed to longitudinal Ampère forces.

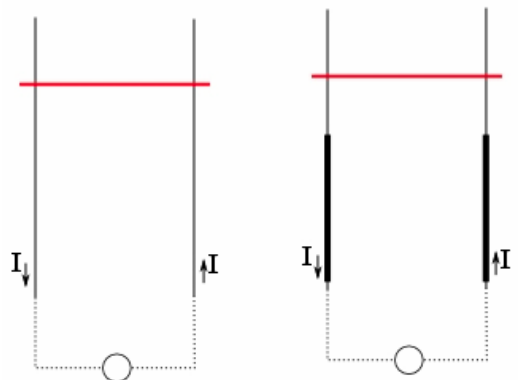


Fig. 8 : The "electromagnetic railgun". In Graneau's version (at right) the crossbar is blocked.

All these experiments were presented as proofs for the existence of longitudinal forces, but alternative interpretations could be put forward as well.

Other experiments aimed at showing longitudinal forces in liquid metals and in plasmas. Although some were very dramatic, we will not mention them here because they are more easily subjected to alternative interpretations.

Longitudinal forces and modern electromagnetism

Longitudinal forces in conductors are absent from most books on electromagnetism. Additionally, their potential effects occur only with unusually high current intensities. Nonetheless, according to some authors, Maxwell's electromagnetism does not exclude the existence of longitudinal stresses that may play a role in the experiments presented above. These stresses arise from the application to conductors of Maxwell's theory of "stress tensors", entirely unconnected to Ampère's force.

The Lorentz force and Ampère force: A contradiction?

Maxwell's equations deal only with electromagnetic field and do not include a force law. For Maxwell, the formulas of Grassmann and Ampère were compatible with his theory, even though he expressed a preference for that of Ampère.

Later, Lorentz expressed the force acting on charged particle q in a vacuum in the presence of magnetic field $\mathbf{B}$:

$$\text{Lorentz' force} \quad \mathbf{F} = q \mathbf{v} \wedge \mathbf{B}$$

It is henceforth the Lorentz force, remarkably verified by experiment, that classic accounts of electromagnetism adopt as an elementary law of force. At any time this force is perpendicular to the direction of the motion of the particle. Thus the current element constituted by a charged particle in motion undergoes a force that, like that of Grassmann, has no longitudinal component.

The expression of the Laplace force, $d\mathbf{F} = i d\mathbf{s} \wedge \mathbf{B}$, is usually presented as a consequence of that of Lorentz. In the models proposed to account for conduction in metals, everything happens as if the forces experienced by the conduction electrons were transmitted to the metallic lattice. The force being perpendicular to the direction of the electrons movement, a metallic conductor element can undergo only transversal forces. The remarkable accuracy of the verifications of the Lorentz law thus would justify abandoning Ampère's formula.

Nonetheless, the justification of Laplace's law by using the Lorentz force has been challenged. A metal conductor is not comparable to an electron beam in a vacuum. We must take into account the physical nature of the current element consisting of positive ions and electrons. According to M. Rambaut and J. P. Vigier, the application of the Maxwell-Lorentz-Einstein laws of electromagnetism to the collective behavior of this ensemble of charged particles leads, in nonrelativistic approximation, to Ampère's formula (1989). Currents in metals would obey Ampère's law, while currents in a vacuum would obey Grassmann's law.

Action at a distance versus field theory and Einsteinian relativity

Still, while modern electromagnetism predicts - and in a simpler way - the same effects as Ampère's formula, why argue - as some continue to do - for the "rehabilitation" of this formula? Is there still room for controversy?

The challenge is actually theoretical. The Ampère force is a force of instantaneous action at a distance. In this respect it is fundamentally inconsistent with Maxwell's theory based on the continuous propagation of electromagnetic action.

The triumph of Maxwell's theory is based on its extraordinary fertility. His equations account for, among other things, the propagation of electromagnetic waves at the speed $c = 300,000$ km/s. The electromagnetic field, which allows the transport of energy, exists in a vacuum devoid of charges. Furthermore, it is Maxwell's theory that "laid down the conditions" in some way for Einstein theory of relativity. The edifice of Maxwell-Lorentz electromagnetism and Einsteinian relativity is thus an apparently incontestable pillar of all twentieth-century physics.

Before Maxwell, physicists such as Weber and then Neumann developed an electrodynamics derived from Ampère's formula. They sought a law of force or of potential, between current elements or between moving electric charges, that would account for all phenomena including the phenomenon of induction - which Ampère's formula did not do. Thus, Weber proposed an elementary force between electric charges consisting of three terms dependant on the distance, the velocity, and the acceleration of one charge relative to the other. The first term is nothing more than Coulomb's law, the second can be deduced from Ampère's formula, while the third accounts for the phenomenon of induction.

Several of the contemporary defenders of Ampère's force pursue the "weberian" electrodynamics project as an alternative to that of Maxwell (A. K. T. Assis, *Weber's Electrodynamics*, 1994 or P. and N. Graneau, *Newtonian electrodynamics*, 1996). The reference to Newton, like references to Ampère or to his successors, is indicative of a project that goes beyond the field of electricity. It is a matter of building a physics based on interactions at a distance between material elements. One could object that Newton or Ampère themselves were far from considering instantaneous action at a distance as the last word in physics. Behind their mathematical laws of gravitation or electrodynamics, which involve only interacting elements and their distance, both were convinced of the existence of a deeper reality based on a continuous transmission in the intermediate space [See the page [*Des théories mathématiquement équivalentes, physiquement différentes*](#)]. However, that does not prevent attempts to account for phenomena customarily described by means of Maxwell's theory using Weber's electrodynamics: radiation effects, the propagation of light... "A lot of theoretical and experimental work will be necessary in this direction," wrote Assis in 1989.

The idea of applying a law analogous to that of Weber for electromagnetism (involving several terms) to gravitation dates back to the 1870s and was considered by Weber himself. One adds to Newton's force of gravitation some terms dependent on the relative speed of masses, on the model of terms added by Weber to the electric force of Coulomb. According to Assis [*Relational Mechanics*, 1999], this weberian mechanics allows the deduction of the first two Newton's laws of dynamics, - the principle of inertia and the fundamental relationship of dynamics, - and to establish the proportionality between inert and gravitational mass. The precession of the perihelion of the planets can be calculated without recourse to the equations of general relativity...

A widespread dissidence that may inspire suspicion?

When one examines the publications of certain supporters of the rehabilitation of Ampère's force, one sometimes finds an opposition to the *mainstream establishment* - "official science" - that is far from being limited to Maxwell's electromagnetism. Someone denounces "the scam of special relativity" or proposes to take advantage of "the infinite energy of the vacuum". Another counters the standard Big Bang theory with that of a stationary universe. The red shift of light from distant galaxies, usually interpreted by the expansion of the universe, would be explained by a theory of "light fatigue". One also finds articles on cold fusion, etc..

These connections can lead to a certain degree of suspicion. However, one will recall that certain beliefs of Ampère, without mentioning his interest in animal magnetism, reeked of heresy to numerous members of the Academy. Certainly, there is hardly any experimental reason for doubting Maxwell's electromagnetism, and it can seem that working to build an alternative electrodynamics is wasting one's energy for nothing. Yet, can one not approve of the *Scientific American* review of Graneau's book, *Newtonian Electrodynamics*: "Highly recommended to the open-minded, and to any who agree with Maxwell about the prudential role of pluralism in ensuring the health of science and, indeed, in ensuring its life." ?"

For more information

GUILLEMOT, Hélène. On avait oublié la force d'Ampère, *Science & Vie*, 879, 1990, p. 38-46.

ASSIS, Andre ; BUENO, M. d. A. *Inductance and Force Calculations in Electrical Circuits*. New York : Nova Science Publishers, Huntington, 2001.

[A bibliography of "secondary sources" about the History of Electricity.](#)

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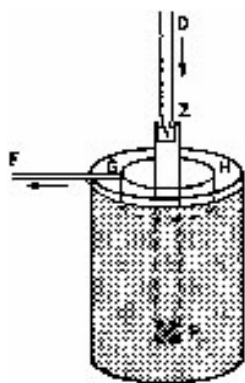
EDITORIAL Winter 1999-2000

Science: To Be, or Not to Be Or, How I Discovered the Swindle of Special Relativity

If we wish to assure the survival of science into the new century, we must begin by clearing up the mess we have made of it over the last. Let's start with the swindle called *The Special Theory of Relativity*. Here we have a roof of wastepaper shingles, set upon the house of fraud that Maxwell built. Einstein's alleged great achievement, that "triumph of 20th century physics," was that he *saved the appearances* of the (then well-known) fraud which the great British faker, James Clerk Maxwell, had constructed over the dead bodies of Ampère, Gauss, Riemann, and, finally, Weber.

This is the story of how I came to recognize the swindle Einstein perpetrated. Like most great liars, Einstein tells you what he is doing, albeit in a devious fashion. Like most discoveries, mine came about through an indirect path. Yet, each step is important in its own way. Bear with me, and you too shall see, if you dare.

First Steps



[SCHEMATIC OF
THE AMPÈRE
APPARATUS
\(1822\)](#)

About two months ago, I read in a column by Jeffery Kooistra in *Infinite Energy* magazine (Issue 27, 1999) of a simple and paradoxical experiment, originally proposed by Dr. Peter Graneau, the author of *Ampère-Neumann Electrodynamics in Metals* and other works. The result so fascinated me that I decided to reproduce the experiment on my own. Two 42-inch lengths of half-inch (i.d.) copper pipe were mounted, each on a separate length of 1 x 3 lumber, and laid parallel to one another, like rails, about 12 inches apart. The opposite terminals of a 12-volt automotive battery were connected to the copper rails.

When the circuit is completed, by placing a 24-inch length of copper pipe perpendicularly across the two parallel pipes, the shorter pipe begins to roll down the track, accelerating to the end, and sparking and sputtering as it goes in a delightful display.

One familiar with the Ampère angular force (see *21st Century*, Fall 1996, "The Atomic Science Textbooks Don't Teach," p. 21), will see that an explanation based on repulsion between elements of current in the parallel rods, and those in the movable, perpendicular portion of the circuit, is at hand—although, the same motion can be accounted for by the *algebraically equivalent* $i \times B$ forces considered in Maxwell's formulations.

The paradox which the designer of the experiment wished to demonstrate comes in the next part. If we replace the 24-inch copper pipe with an equivalent length of steel pipe, the steel pipe rolls in the opposite direction! Why? I asked Dr. Graneau, who was kind enough to provoke my added interest by telling me that he didn't know, and that he didn't know of anybody who did.

Ampère's Theory of Magnetism

It seemed to me, first of all, that the steel pipe must be experiencing a magnetization under the influence of the current. If so, the question, as I saw it, remained of what was the influence of the other parts of the circuit on the presumed magnet. I recalled that Ampère devoted the largest portion of his famous 1826 *Memoire* to developing a theory of magnetism, attempting to subsume the entirety of magnetic effects known to him under his law for the force between current elements.

To accomplish this, he made use of the beautiful concept (suggested to him by his close friend, Augustin Fresnel) of the "magnetic molecule." By this he meant a small, resistance-free, circular current, which he believed to be present in the atomic structure of all things. In the case of ferromagnetic materials, Ampère supposed these molecules to be aligned in parallel columns, compounding their force to produce the total magnetic effect.



[WILHELM
WEBER'S
UNIPOLAR
INDUCTION
MACHINE OF
1839](#)

In the *Memoire*, Ampère shows that a magnetic solenoid would produce a rotational moment on a current element, or portion of a circuit, located outside; but that in the case of a complete circuit, there would be no moment. I wondered if, in the case of the backward-moving steel pipe, the other parts of the circuit formed by the copper rails might not act separately from the portion of the circuit passing through the steel pipe. Another experiment, prepared for a classroom demonstration on these topics, had suggested such a possibility.

In the latter case, I wished to show that a magnetized, hollow steel cylinder acted differently than did a classical Ampère solenoid (which had been made by winding a wire around a hollow plastic tube of the same dimensions as the steel cylinder). I had had difficulty achieving any significant magnetization of the steel cylinder, which was made from a section of tubing used for carrying electrical conduit—what electricians call EMT. However, shortly before the classroom demonstration was to take place, I noticed that if the steel tube was wound with wire like the plastic one, and a current run through it, the difference in the form of the magnetization could be demonstrated. To wit, an iron nail or other magnetizable object is drawn into the center of the Ampère solenoid, but only to the outside ends in the case of the steel cylinder.¹

At the time, I concluded, without giving it much thought, that the magnetization produced in the steel cylinder when the current was flowing was simply the predominant effect, making the contrivance behave (when the current was on) more like a permanently magnetized piece of steel than an Ampère solenoid.

After reading a part of the Ampère *Memoire*, I saw the possibility that this same sort of effect might be at work in the case of the backward-rolling steel pipe. It might be possible to convert the case Ampère describes, of a rotational moment created by a solenoid on part of a circuit, to the case in hand. The calculation is, however, difficult, and the experiments necessary to verify it even more so. I have not had the opportunity, yet, to pursue it.

Maxwell's Fraud Summarized

Had anyone else done so? Unfortunately, the Ampère *Memoire* is almost never read today; only a small portion of the 200-page work was ever translated into English, and even French speakers rarely, if ever, trouble to work through it. The reason is that James Clerk Maxwell, in the middle of the 19th century, made a new mathematical formulation of the laws of electricity, which he claimed was *algebraically equivalent* to that of Ampère and Ampère's successor in the development of the electrical laws, Wilhelm Weber.

Not only did Maxwell make this formulation, but, one must add in all honesty, British political-military hegemony at the time *imposed* the new view on many reluctant, sometimes even obstinately so, opponents on all continents.

Maxwell's formulation, however, eliminated consideration of the angular component of the force between current elements. It also removed the most fundamental of Ampère's assumptions—the unity of electricity and magnetism—by introducing the concept of a *magnetic field*. There is no *magnetic field* in any of the writings of Ampère, nor of his successors in electrodynamics, Carl Friedrich Gauss, Wilhelm Weber, and Bernhard Riemann. Magnetism, for them, is considered an epiphenomenon of electricity; it is the force of electrodynamic attraction or repulsion acting between circuits of electricity, called *magnetic molecules* (and which came to be known later as *electrons*).

This forgotten part of the history of the subject is most important to what we are about to show.

The First Unipolar Machines

But to return to the thread of our story, I soon became aware of some closely related developments. In 1840, Wilhelm Weber, who then shared with Gauss the leadership of the worldwide association for the study of the Earth's magnetic forces known

as the *Magnetische Verein*, published in the journal of that society a paper titled “Unipolar Induction.” In it, he described his study of a phenomenon first discovered by Ampère.

Begin with a cylindrical steel rod, magnetized along its axis. If the lead wires from a battery are brought into contact with the magnet such that the magnet is not constrained in its motion (as by brushes), one brush touching it at the top of its central axis, and the other along the circumference of the cylinder and roughly midway between the two poles, the magnet will rotate around its own axis for as long as the current continues to flow. Ampère created such an electric motor, which Faraday had deemed impossible, in 1822.

Unipolar induction, a term apparently due to Weber, by which he seems to mean induction of an electrical current in one direction only (pure direct current in our modern terms), refers to the converse situation. The magnet is rotated, as by a crank, generating an electric current in the lead wires. Weber had some difficulty accounting for the phenomenon, until he modified what he thought was Ampère’s conception of the magnetic molecule to suppose that two separate magnetic fluids (north and south) were contained within the magnetic molecule, and that the portion of the current flowing through the magnet followed a path midway between them.

After Weber, many more studies were made of the unipolar induction. In the 1870s, E. Edlund in Sweden showed that the magnet could be kept stationary, and, instead, a steel cylinder which surrounds it, but which need not be in physical contact with it, could be rotated, producing the same effects. The American physicist E.H. Hall mentions the researches of Edlund as having contributed in some important way to his 1879 discovery of the transverse current phenomenon, now known as the Hall Effect.²

In another form of the unipolar induction, a rotatable steel disk is situated between two steel plates bearing opposite magnetic poles. Brushes with lead wires running from them are brought into contact with the disk at a point near its center, and at a point, or points, along the circumference. Upon rotation of the disk, a significant current is generated in the wires. Description of this form of the apparatus, called a *unipolar* or *homopolar generator*, can be found in older textbooks on electrical principles.

In one book, I learned that such machines were being produced commercially by the General Electric and Westinghouse Companies in the 1920s. Such devices can produce very high, pure direct currents, without the need for rectifiers or commutators, but have the disadvantage of producing only low voltages.

Forbidden Words

Readers familiar with the ways of physicists may know, however, that raising the topic of unipolar generators and motors among them is most likely to produce grimaces, embarrassed smiles, or other looks of dismay. The reason for this only became clear to me a short time ago. Up to that time, I had naively thought that there was some doubt as to the actual existence of the effect, so negative is the reaction to the mere mention of the words.

Now I understand, what many already knew, that it is part of the codified religion of the self-anointed priesthood known as academically accredited 20th-century physicists, that such a topic is not to be discussed. The reason is, that Einstein said so.

I began to suspect so just recently, when, a friend, after seeing a demonstration of the backward-rolling steel pipe, opened up a 1950s textbook on electrodynamics to the section on “homopolar generators.” In it, the author described a generator of the rotating disk type just described above. The author went on to say that if the disk is kept stationary and, instead, the magnetic plates surrounding it are rotated, no current is generated!

Students often have difficulty grasping why this should be so, the author tells us. But, he explains to them that they must understand that when the magnets are rotated, the magnetic field lines do not rotate with them!³ Further, the textbook author suggests, one must consider the *inertial framework* of the observer and the apparatus. Finally, he tells us, that when students still don't yield, he clears things up by presenting them with another case. He then describes a more complicated experiment involving the relative motion of magnet, steel bar, and ammeter, in which eight different outcomes are possible. And there the chapter ends. Surely, then, everything is clear.

Enter Einstein

I am in some ways naive, but one does not live a large portion of one's life in New York City without developing a certain instinct for knowing when he is being swindled. A look into yet another but older textbook (under what perverse impulsion I know not), brought me nearer to the truth. For here, on page 8, just upon entering the topic of electrostatics, we are told that, before going any further, we must become familiar with the concept of *inertial frames*. (That was 1930, when everybody was not so familiar with this idea.) For situations arise in which an observer in one inertial frame will measure an electric field and no magnetic field, while another might measure both an electric and a magnetic field, for example. If we do not take into account inertial frames, we are warned, many problems in electrodynamics, especially those involving rotating magnets will create difficulties for us.

Just at that point I began to suspect the exact nature of the swindle. Was it possible, that—despite all the talk of moving trains, clocks, and shrinking rods—the anomaly being addressed in Special Relativity was actually the much more mundane case before me—the asymmetry between motion of the magnet and motion of the disk? Then I remembered the title of Einstein’s famous paper, “On the Electrodynamics of Moving Bodies.” Suddenly, its first paragraph made sense:

“It is known that Maxwell’s electrodynamics—as usually understood at the present time—when applied to moving bodies, leads to asymmetries which do not appear to be inherent in the phenomena. Take, for example, the reciprocal electrodynamic action of a magnet and a conductor. . . .”

Was Einstein talking about anything other than the anomaly of the sort manifested in the unipolar generator? If there were any doubt, one needed only to turn to “II. Electrodynamical Part, Section 6. Transformation of the Maxwell-Hertz Equations for Empty Space. On the Nature of the Electromotive Forces Occurring in a Magnetic Field During Motion.” There, in the last paragraph we read:

“Furthermore it is clear that the asymmetry mentioned in the introduction as arising when we consider the currents produced by the relative motion of a magnet and a conductor, now disappears. Moreover, questions as to the ‘seat’ of electrodynamic electromotive forces (unipolar machines) now have no point.”

And so, a true physical anomaly has been caused to disappear by the introduction of an arbitrary postulate—and an absurd one, at that. Thus are Maxwell’s equations “saved.” Could a magician do better?

There, dear reader, is the fraud—or a big part of it—which today’s well-paid fraternity of professional physicists are committed to defend.⁴ Heed and respect these hoaxsters if you wish. You will pay, like Faust, with your soul. Science, like all creative practice, is a precious tradition of thought, which begins with a profound and religious love for one’s fellow man, and most of all, for those among one’s predecessors who have ventured into that fearful territory “from whose bourn no traveller returns”: the realm of independent, creative thought. Nothing will so quickly turn a gifted thinker into a hopeless sack of lost potential, as moral compromise.

There is the challenge for science, as we enter the new millennium.

—*Laurence Hecht*

NOTES

1. This was the subject of an early challenge by Michael Faraday to

Ampère's hypothesis of the magnetic molecule. Faraday reasoned that if Ampère's conception were correct, the two cylinders should show the same magnetic effect; but his experiments showed that they behaved differently. Ampère showed that Faraday did not understand the conception: the large circular windings of the solenoid are only macroscopic analogues of the very small circular currents hypothesized to reside within the atomic structure of the magnet. Thus, the geometry of the currents in the two cylinders is entirely different, and Faraday's experimental conception is fundamentally flawed.

2. It might, or might not, be relevant to the case at hand that, shortly after his discovery of the transverse current, which was accomplished in a thin layer of gold deposited on a glass plate, Hall discovered that iron produces a transverse current in the opposite direction.

3. Professor O'Rahilly, author of *Electromagnetics* (1938) calls this argument, which had already been employed in his day, "hypostasizing one's own metaphor." Today, we might use blunter language.

4. Let us allow each man the benefit of the doubt. Some among this fraternity have been so credulous, in their pursuit of fame or money, as to be truly ignorant of the fraud they are paid to uphold. Today, even educated physicists usually lack the historical background to understand how troubling was the challenge posed to Maxwell's system by such asymmetries. Maxwell's nasty fraud—the usurpation of half a century's hard work, steered by the greatest mathematical physicist of modern times, Carl Friedrich Gauss—was in trouble. And people were alive who knew, and still resented, the arbitrary and entirely *political* manner in which the Ampère-Gauss-Weber electrodynamics was unseated.

Maxwell, who did no more than create a mathematical system which successfully misrepresented all the hard work of Ampère, Gauss, Weber, Riemann and others, had made a big blunder, or several. The Ampère-Gauss-Weber electrodynamics was relativistic, in a non-silly sense; it was atomistic; Gauss knew that the propagation of electrodynamic force was not instantaneous (Weber, Kohlrausch, and Riemann had measured it in 1854, years before Maxwell ever proposed the electromagnetic theory), and was seeking since no later than 1835, a "constructible representation" for it, as Gauss put it in an 1845 letter.

So Einstein "saved the appearances" of Maxwell's flawed electrodynamics. He should be called the modern Ptolemy. Maxwell is the true "Newton" of modern times. Just as one of scientific history's most over-inflated impostors, Isaac Newton, reformulated Kepler's work into an inferior formal system, so Maxwell did the same for the work of Ampère, Gauss, Weber, and Riemann.

Perhaps the defenders of Maxwell's system prefer to remain in ignorance for the simple reason that the patent untenability of their position becomes only more clear, the more they know of its true history. For example, let one of the anointed priests of this profession respond today, to the devastating blow to their entire straw edifice which Ampère had struck in an 1822 letter to Faraday. Explaining that a perpetual motion was impossible, Ampère showed that the force between current elements which could be turned into a continuous rotational motion, had to come from the work done within the battery. However, such was not the case if one presumed—as did Biot, Laplace, and later Maxwell—that the force between magnet and magnet could be made equivalent to that between current element and current element. For in that case, continuous rotational motion would be possible between two magnets, a conclusion which violates the principle of energy conservation:

"... dans les autres théories, on devrait pouvoir imiter, avec des assemblages d'aimants disposé convenablement, tous les phénomènes que présentent les fils conducteurs; on pourrait donc, en faisant agir un de ces assemblages sur un autre, produire dans celui-ci le mouvement continu toujours dans le même sens; ce que dément l'expérience" (cited in Blondel, *op cit.*, p. 117).

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